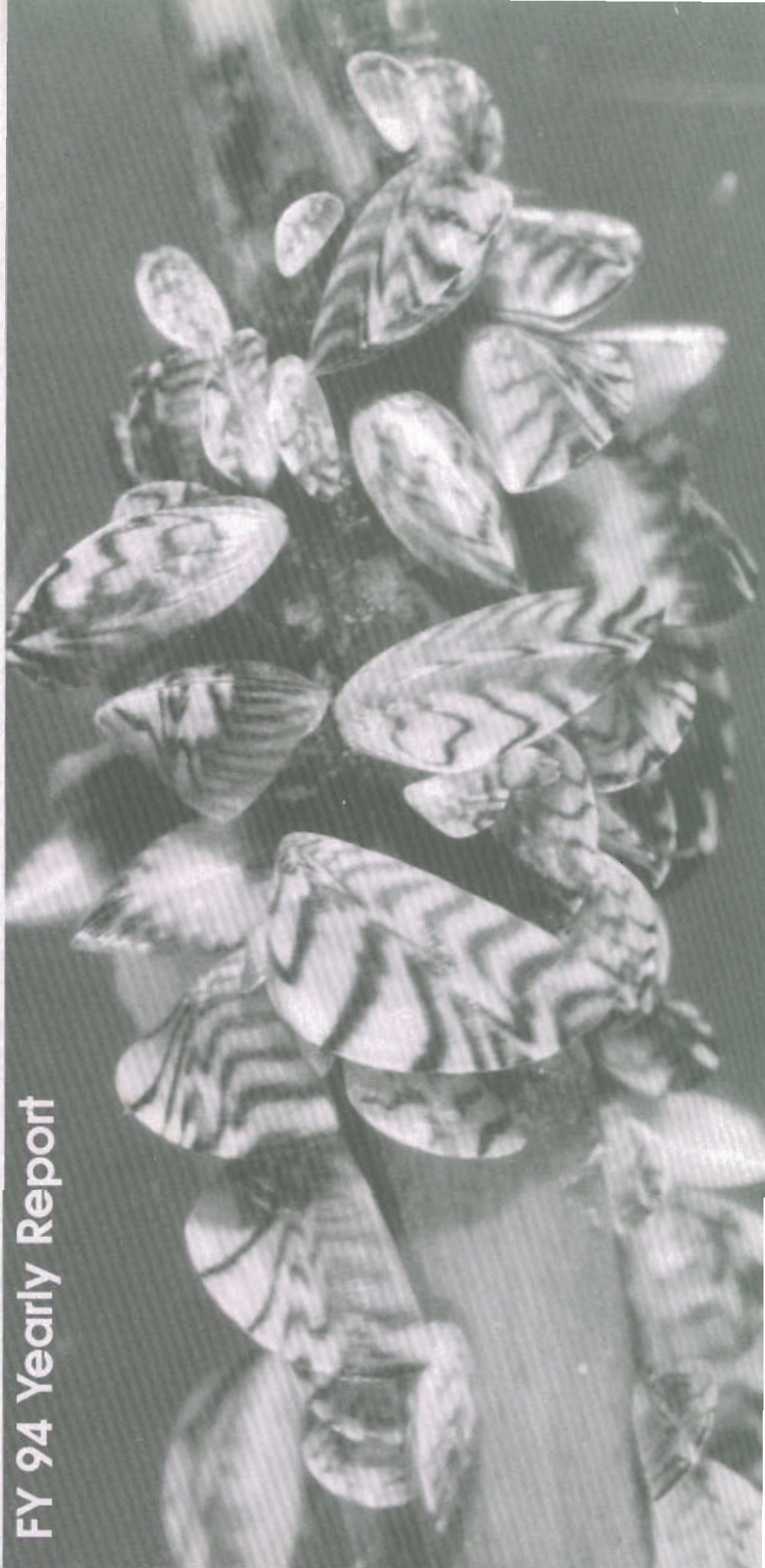


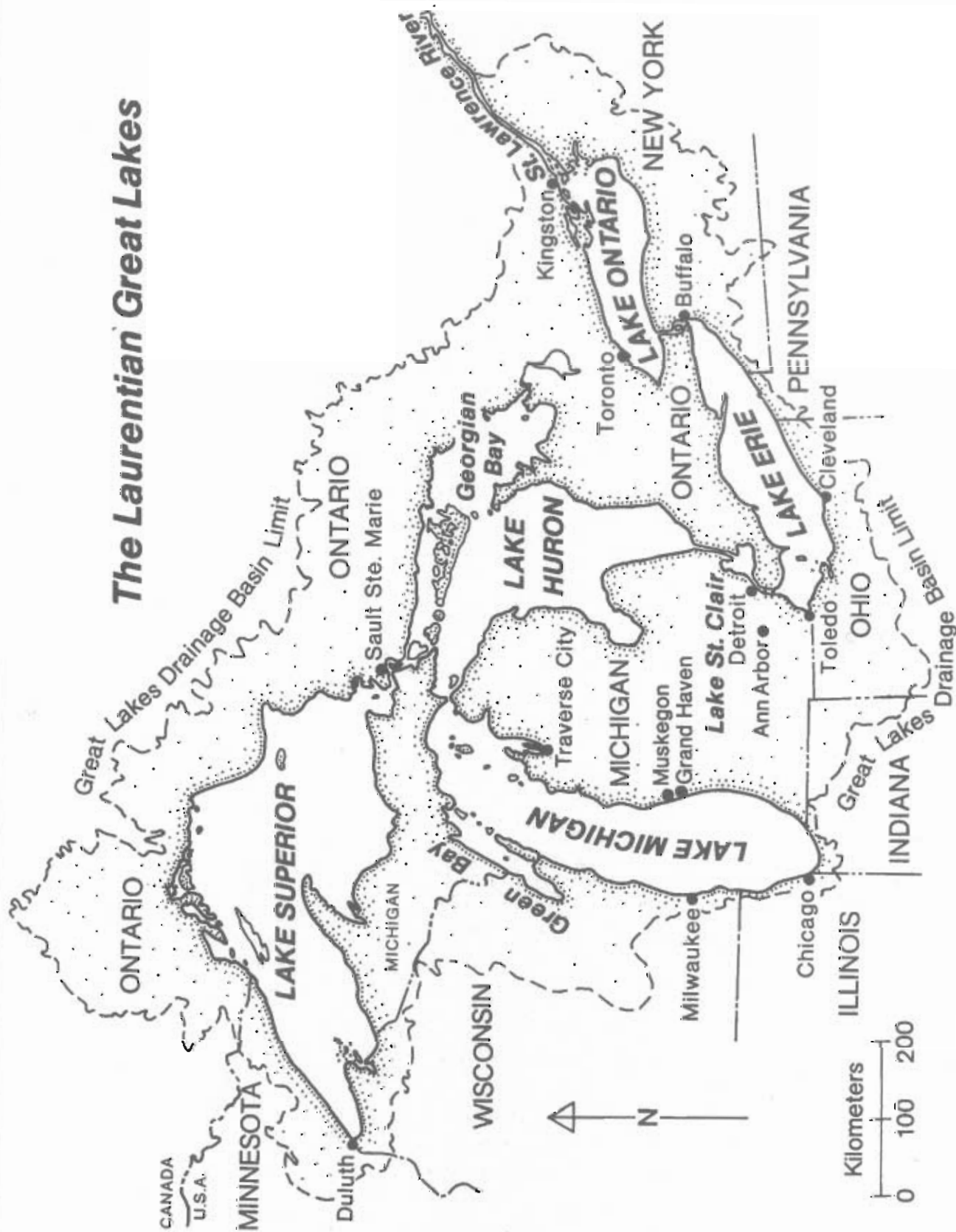
Great Lakes
Environmental
Research
Laboratory



FY 94 Yearly Report



The Laurentian Great Lakes



NOTICE

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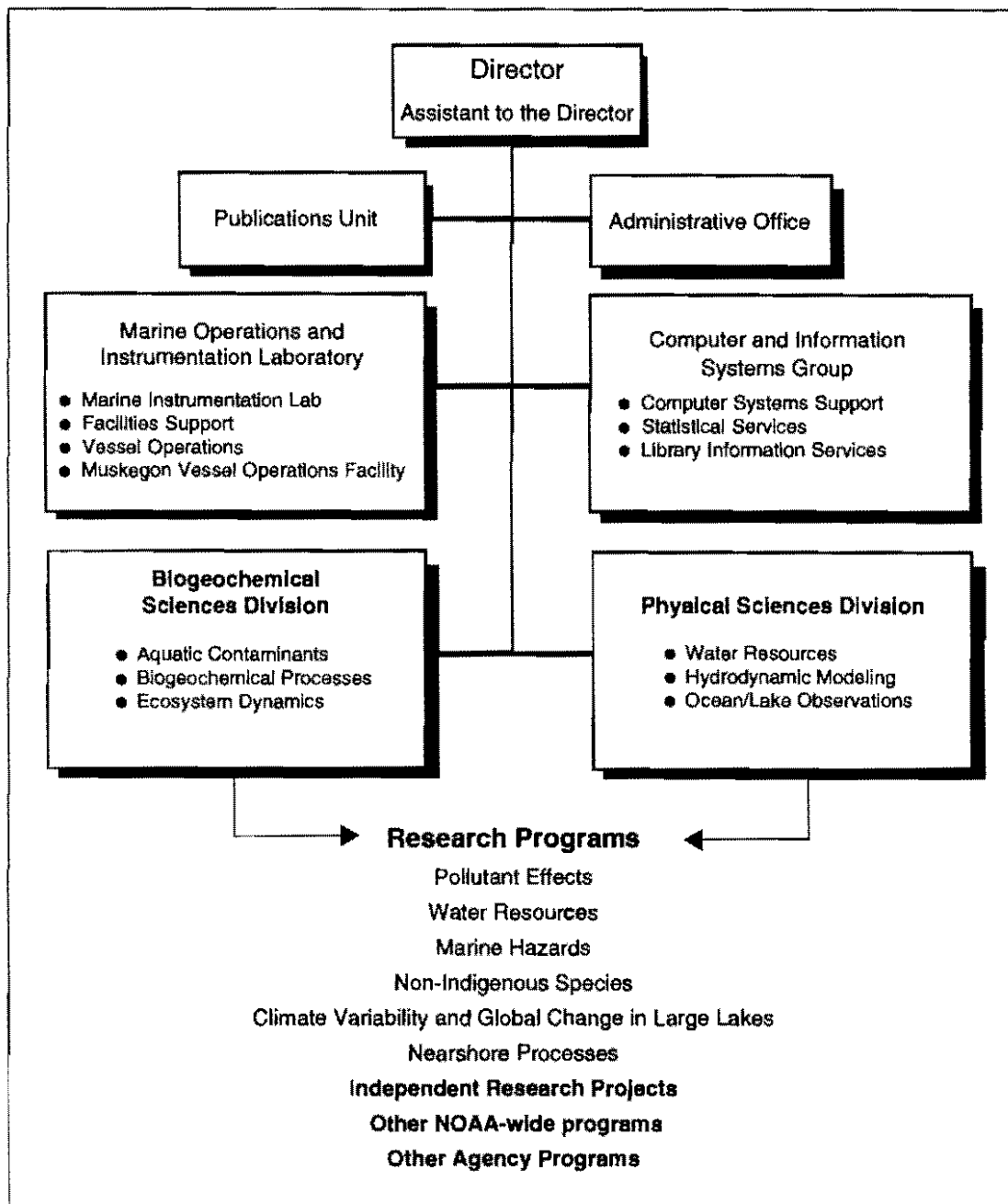
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INTRODUCTION

The Great Lakes Environmental Research Laboratory (GLERL) conducts integrated, interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine waters, with special emphasis on the Great Lakes. Primary research activities are organized into research programs that are in accordance with NOAA's mission and Strategic Plan and that address critical Great Lakes and marine coastal problems: Pollutant Effects, Water Resources, Marine Hazards, Non-Indigenous Species, Climate Variability and Global Change in Large Lakes, Nutrient-Enhanced Coastal Ocean Productivity (NECOP), Great Lakes CoastWatch, and Nearshore Hydrodynamics. These research areas correspond to Strategic Plan Elements in NOAA's Environmental Stewardship Portfolio and the Environmental Assessment and Prediction Portfolio.

GLERL enhances its research activities through the Cooperative Institute for Limnology and Ecosystems Research (CILER), which is a joint research enterprise of the University of Michigan, Michigan State University, and GLERL. CILER promotes collaborative research between scientists from throughout the Great Lakes basin, addressing a wide variety of research topics of mutual interest. Many of the projects described here involve participation between GLERL staff and CILER Fellows, Visiting Fellows, and other scientific staff.

This report describes the significant activities and accomplishments during the period October 1, 1993 - September 30, 1994. For general information on how to obtain GLERL products, see the Facilities and Services section of this report.



GLERL's Organization Structure

POLLUTANT EFFECTS

The goal of this program's research is to increase our understanding of the dynamics and effects of contaminants in the ecosystem. The research effort combines process studies and mathematical modeling and focuses on toxic organic contaminants. Because the role of contaminated sediments is the least well understood, but one of the most important, of the exposure pathways, the present research is focused on sediment-associated contaminants and how benthic organisms are affected by exposure to these sediments.

Contaminant Effects and the Relationship to Exposure

(Project Scientist: Landrum)

The goal of this project is to explore the relationship between contaminant exposure and contaminant effects on biota. To accomplish this goal, new bioassays are being developed to follow the body burdens required to elicit the effects of these contaminants. In FY 94, preliminary toxicity and bioaccumulation experiments with fluoroanthene were performed. The calibration of the 28-day mortality bioassay for the amphipod *Diporeia* was completed, resulting in the creation of an annex to the American Society for Testing and Materials (ASTM) Standard E 1383, which established the use of *Diporeia* as a bioassay organism for mortality testing. Data analyses on toxicity and toxicokinetics of pyrene in *Diporeia* were completed.

Physical and Biological Diagenetic Processes in Sediments

(Project Scientist: Landrum)

This research examines how contaminants affect the activities of benthic invertebrates, and how the activities of benthic invertebrates contribute to sediment bioturbation.

In FY 94, GLERL completed its contribution to a model of the oligochaete worm *Stylodrilus heringianus* reworking of DDT-contaminated sediments.

Long-Term Trends in Benthic Populations

(Project Scientist: Nalepa)

The objectives of this project are to determine trends in benthic invertebrate populations in selected areas of the Great Lakes and determine the significance and reasons for such trends. Starting in 1993, this project was expanded to incorporate the requirements of the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) for the Great Lakes.

In FY 94, samples were obtained from southern Lake Michigan and Lake Superior and preserved, and the benthic organisms were separated from the rest of the material. Counting and identification of oligochaetes (worms) and chironomids (midges or insect larvae) were completed for 1993 samples.

Bioavailability of Sediment-Associated Toxic Organic Contaminants

(Project Scientist: Landrum)

Assessment of the risks associated with contaminated sediments requires (1) determination of the conditions under which sediment-associated toxic organic compounds accumulate in benthic organisms, (2) determination of whether the toxins are transferred up the food chain, and (3) development of models for describing bioaccumulation.

In FY 94, the assimilation efficiencies for both *Diporeia* and the worm *Lumbriculus variegatus* were deter-



A GLERL scientist collects sediment samples aboard the R/V *Shenehon* for analysis at the Ann Arbor laboratory.

the bioavailability of the PAH, suggesting that even simple manipulations can influence the results of laboratory bioassays used in assessing sediment-associated contaminants.

Assessment of Extractability and Bioavailability

(Project Scientist: Van Hoof)

A major topic in assessing the exposure of benthic organisms to persistent hydrophobic organic compounds (HOCs) is the relative importance of uptake via the bulk overlying water, interstitial pore water, or ingestion of sediment. This project is to assess the importance of environmental factors such as contact time and weathering on HOC sorption to sediment and bioaccumulation by the benthic organism *Diporeia* sp. In addition, the potential of using chemical extraction kinetics to assess bioavailability is being explored.

In FY 94, the development and testing of extraction and analytical methodologies necessary for a study of bioaccumulation of laboratory-dosed and field-resident PAHs in Little Scioto River (Ohio) sediment was completed. Cores from Lake George, a part of the St. Marys River, were used in a *Lumbriculus* bioaccumulation bioassay. The bioavailability was expected to decrease with distance downcore as a result of increased contact time of contaminants with sorbent, in this case sediment. However, no change in bioavailability was observed for PAHs between 4 and 48 cm. These results have not yet been explained; examination of the data continues.

mined. The assimilation efficiency was found to depend, in part, on the assumptions used for the calculations. Because none of the standard methods are assumption-free, these results demonstrated that a significant factor in determining the assimilation efficiency is, in fact, the methodology employed.

Analyses of sediments from five stations in Lake Michigan plus Florissant soil (a reference sediment) were completed and evaluated for factors that affect the bioavailability of sediment-associated contaminants. The variance among the Lake Michigan stations was reduced with carbon normalization. However, the variance for the Florissant soil data was not significantly improved by carbon normalization. Sediments from Florida, South Carolina, Missouri, across the

Great Lakes, and Finland were obtained and will be tested to determine if the same failure of the carbon normalization technique would occur if the materials employed were all aquatic sediments.

The bioavailability of polycyclic aromatic hydrocarbons (PAHs) was examined to determine the appropriate conditions for the use of *Lumbriculus variegatus* as a bioassay organism. No differences in the uptake kinetics were observed for laboratory-dosed vs. field-resident PAH in contaminated sediments when the PAHs were of lower molecular weight, but significantly slower uptake kinetics were observed for the higher molecular weight PAHs in field samples relative to laboratory dosed PAHs. Additionally, mixing of the sediments was shown to increase

WATER RESOURCES

Great Lakes water is used for drinking, power generation, commercial shipping, and recreation, and it supports an extensive commercial and sport fishery. Both natural (evaporation) and anthropogenic (diversions, consumption) influences threaten this valuable resource. The purpose of this program is to develop improved predictions, climatology, statistics for decision-making, and process studies, and to interface with policy and decision-makers.

Great Lakes Hydrology and Ice Databases

(Project Scientists: Assel & Lee)

This goal of this project is to develop and provide new or improved historical hydrometeorological and ice cover databases. Geographic information databases of the Great Lakes basin will be developed and maintained and the hydrology and ice cover databases will be linked with the geographic databases for spatial analysis.

In FY 94, digital station data were received from the National Climatic Data Center and were used to provide precipitation metadata quality control for scanning accuracy and consistency. Pre-1948 monthly temperature data for the Great Lakes states were also digitized. Development of a Geographic Information System (GIS) database of daily meteorological data for the United States was initiated, and data through 1993, as well as some Canadian data, were added. A data rescue subproject was initiated with funding from NOAA's Earth System Data and Information Management (ESDIM) Program. Under this subproject, a catalog of all historical ice charts at GLERL for the decade of the 1980s and early 1990s was completed, and ice charts for 1993 and 1994 were obtained from the National Snow and Ice Center and the Canadian Atmospheric Environment Service.

Great Lakes Water-Level Statistics for Decision-Making

(Project Scientists: Quinn, Lee, Herche)

The long-term objective of this project is to develop improved water-level statistics that reflect (1) existing hydrologic and hydraulic conditions, (2) the long lag response of the lakes to meteorological variability, (3) changes in climatic regimes, and (4) the needs of diverse Great Lakes decision-makers. In FY 94, a study of covariance properties of annual net basin supplies to the Great Lakes was completed. A major finding was that the residual method used operationally to determine net basin supplies can induce an artificially long tail in the autocorrelation function. This observation has important ramifications to efforts to simulate Great Lakes water levels, because simulation results are quite sensitive to the covariance structure of the annual net basin supplies.

Next-Generation Runoff Models

(Project Scientist: Lee)

GLERL has developed conceptual-model-based techniques for simulating moisture storages and runoff from the 121 watersheds draining into the Laurentian Great Lakes. This project will refine runoff models so that they can be integrated with atmospheric process models in another task and can incorporate recent advancements in measurements of hydrometeorological data. Linking the surface hydrology process models with atmospheric process models will allow feedback be-

tween climate and land surfaces and result in more-accurate estimates of regional and local climate change impacts. The goals of this project are (1) to develop the next-generation runoff models with gridded land surface parameterizations from 1 to 30 km, which can be incorporated into mesoscale atmospheric models and water supply simulation and forecasting packages, and (2) to implement the improved models at agencies responsible for water resources forecasting and management.

In FY 94, a high-resolution (100 m \times 100 m) digital elevation model of the Great Lakes basin was completed. Exploratory datasets of watershed delineation, stream network, flow direction, and flow accumulation were derived from the digital elevation model. Soil data for each of the Great Lakes states and two Canadian provinces were acquired. Land use and land cover data were also acquired for the United States, and comparable data for Canada were located. A review of the Regional Atmospheric Modeling System (RAMS) atmospheric model land surface parameterizations was completed. Some potential programming errors were identified, and decoupling of the land-surface parameterizations component was initiated.

Water Resources Forecasting System (Project Scientist: Croley)

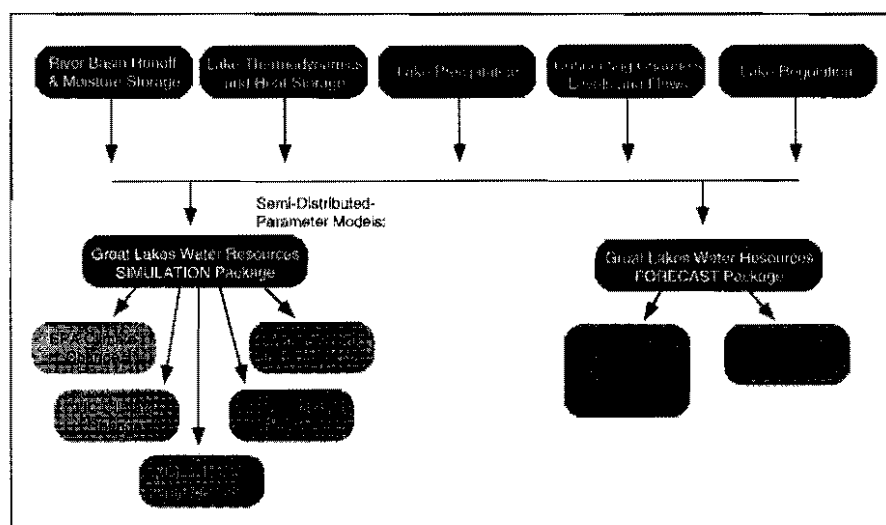
The availability of adequate water resources to support the Nation's continuing growth and infrastructure will be one of the major issues of the 21st century. Forecast systems that provide water resource forecasts of variables over large areas at time scales of several days to several weeks or months are needed. NOAA's program to build a nationwide Water Resources Forecasting System (WARFS) provides for GLERL to develop the water resource forecasting capability in the Great Lakes basin.

The goal of this project is to build an operational water resource forecasting system for the Great Lakes basin, including development of a new suite of desired forecast products and integration of models, data management, and analysis techniques. In FY 94, the conceptual plan and related documentation were completed to outline this project through the year 2000.

Coupled Hydrosphere- Atmosphere Research Model (Project Scientist: Croley)

Understanding how the Great Lakes affect the weather, and understanding how the weather affects the Great Lakes will allow more-informed decisions to be made concerning potential impacts of altered climate and anomalous (wet) seasonal weather patterns, such as that experienced in parts of the midwest during the summer of 1993. The main goal of this research is to assess the hydrologic-atmospheric dynamics within the Great Lakes basin. This is supported by three objectives: (1) develop a Coupled Hydrosphere-Atmosphere Research Model (CHARM) from existing atmospheric and hydrologic models by using two-way dynamic interactions, (2) enhance the model with second-generation surface parameterizations for lake thermal flux and runoff, and (3) refine earlier climate change estimates and estimates from other mesoscale modeling efforts by developing one-way linkages between them and the Great Lakes hydrology models.

In FY 94, the incorporation of existing runoff and lake thermodynamic models into the modeling system was completed, and ancillary software was developed to configure National Meteorological Center (NMC) input and analyze CHARM output for monthly means.



GLERL's Water Resource Models and Past Applications.

MARINE HAZARDS

Marine hazards are the result of a variety of environmental phenomena and pose threats of loss of life or property and social or economic disruption. Large waves, high and low lake levels, heavy snowfalls, ice, and erosion are significant hazards in the Great Lakes system and (with the exception of low lake levels) in other coastal areas as well. Human-caused hazards also pose serious threats, especially spills of petroleum products and chemicals. This research program provides models and other service products to assist in marine hazard prediction, emergency response, damage prevention and reduction, and more effective management of water resources.

Lake Circulation Studies and the Great Lakes Coastal Forecasting System

(Project Scientists: Schwab, McCormick, & O'Connor)

Numerical simulation and prediction of temperatures and currents in the Great Lakes is the focus of this research program. In FY 94, the title of the Great Lakes Forecasting System (GLFS) was changed to Great Lakes Coastal Forecasting System (GLCFS), to alleviate confusion between this and a water resources forecast system also being developed at GLERL. The GLCFS is a collaborative effort between NOAA/GLERL and Ohio State University. The objectives of this GLCFS project are (1) to develop and test improved hydrodynamic models that can simulate and predict the three-dimensional structure of currents and temperatures in the Great Lakes, (2) to extend the models to simulate and predict the transport and diffusion of pollutants and nutrients, and (3) to couple these models to aquatic ecology and water quality models. The goal of GLCFS is to implement and test a system for real-time prediction of the physical status of the Great Lakes based on the hydrodynamic models developed under this project. A user/client meeting was held with the National Weather Service (NWS) to discuss plans for operational use of the GLCFS.

Lake Erie nowcasts were extended to four times a day for use by EPA in a Lake Erie study. Hourly water level data from the Buffalo, Toledo, and Cleveland National Ocean Service

water level gauges were compared with the 1993 GLCFS nowcasts. Agreement was excellent, indicating that the objectively analyzed wind fields used to drive the nowcasts are very accurate. Surface water temperatures from two weather buoys in the lake were also compared with nowcast values for the entire year. Both average daily temperatures and hourly deviations from the daily mean (diurnal cycle) agreed quite well, although there were periods in the spring when the model temperatures were lower than observed temperatures, and periods in the fall when model temperatures were higher than observations. The circulation model for Lake Erie was also evaluated in a hindcast mode against current meter data collected in an extensive field program in Lake Erie in 1979. The simulated water temperatures, and to a lesser extent the velocities, show poor comparisons at nearshore locations, indicating that the calculations in the coastal and thermocline areas need to be improved. The circulation model was also tested in a number of idealized cases where specific processes can be isolated. These tests led to a new explanation for the persistent cyclonic circulation observed in stratified lakes.

Coastal Hazards

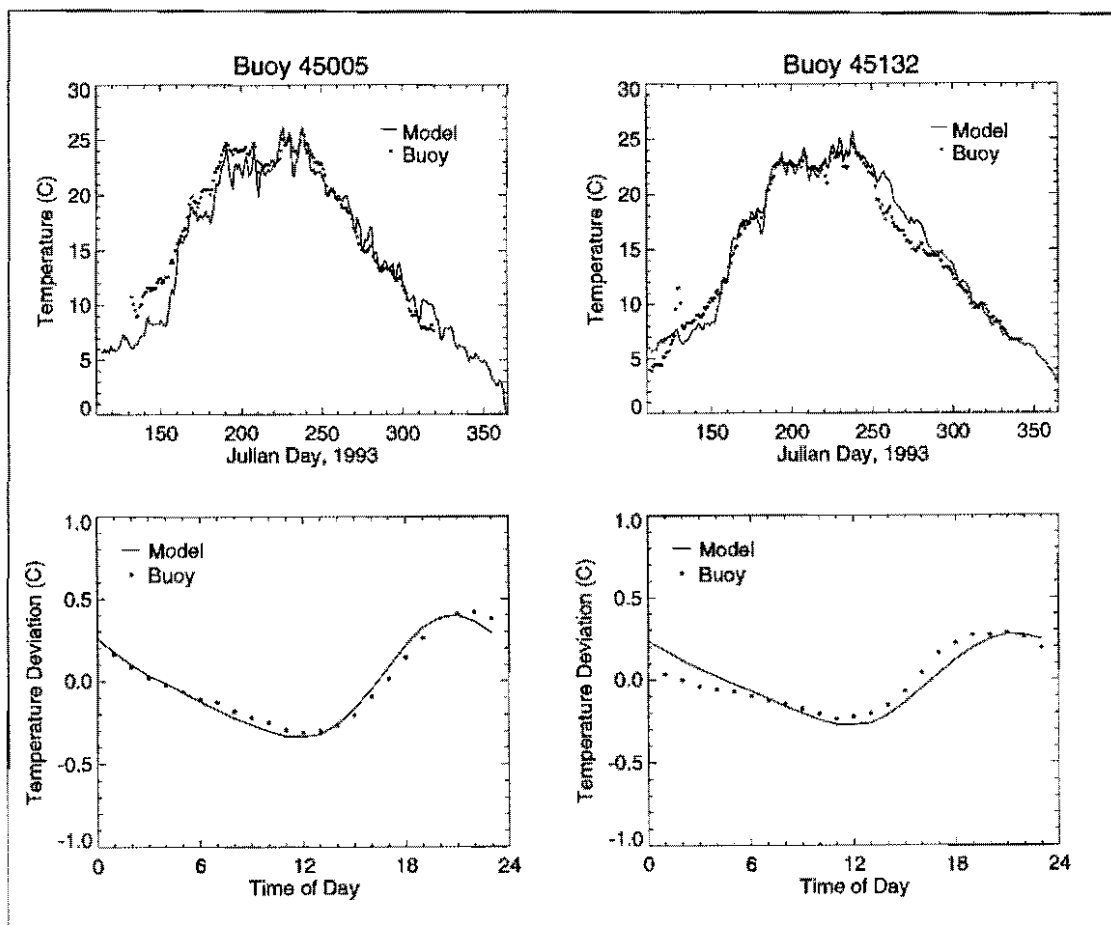
(Project Scientist: Schwab)

Meteorological and oceanographic conditions in coastal areas can sometimes become dangerous enough to cause significant damage to property (boats, ships, structures, etc.) and re-

sult in loss of human life. The primary factor responsible for producing hazardous conditions is the marine surface wind. The wind is a hazard by itself for boats, ships, and other structures, but the danger to these is increased by wind-generated waves, storm surges, and generated currents. This project's goal is to develop models for coastal wind forecasts. Testing, evaluating, and refining marine boundary layer physics in the mesoscale models for wind predictions over the Great Lakes are the primary objectives. Specifically, the focus is on testing the NWS/NMC Eta-coordinate model for the Great Lakes region and looking for necessary changes in the grid represen-

tation of the coastline geometry and topography, and modifications to the boundary layer physics to improve its performance.

In FY 94, Eta model winds from the 40-km experimental version were used to drive a free-surface hydrodynamic model for 16 cases. Results were compared with runs made with objectively analyzed wind observations. The 40-km semi-operational Eta model was replaced by a 29-km version in May 1994, and forecasts from the new version were acquired and archived.



Surface water temperatures from two weather buoys were compared with GLCFS values for average daily temperature and hourly deviations.

NON-INDIGENOUS SPECIES

The objective of this program is to expand our knowledge of the biology and the ecological effects of non-indigenous species in the Great Lakes. Research involves field investigations to monitor ecosystem changes and community response to these species and examines biological traits of the organisms themselves. Research also includes laboratory experiments to determine metabolic features and feeding rates and examines toxicokinetics and bioaccumulation of toxics.

Effects of the Zebra Mussel on the Lower Food Web of Saginaw Bay

(Project Scientists: Nalepa, Fahnenstiel, & McCormick)

The objectives of this project are (1) to identify and understand changes in the abundance, biomass, and composition of the lower food web of Saginaw Bay that have resulted from the invasion of the zebra mussel (*Dreissena polymorpha*), (2) to construct a model of carbon flow through the system and determine major changes in pathways, which may have been caused by the zebra mussel disrupting the ecosystem, and (3) to monitor changes in the abundance and distribution of zebra mussels in the bay.

During FY 94, water quality data from 1991 to 1993 were analyzed, and processing of benthos and zooplankton samples through 1993 was completed. Data about zebra mussel abundance, size, length-weight parameters, and seasonal clearance rates were organized and summarized. The third (and final year) of current-meter moorings across the outer bay was completed; all moorings were retrieved, and 3 years of raw current-meter data were compiled. Two years of meteorological data from the GLERL Meteorological Station established at Gravelly Shoal were compiled. The 1991-1993 compilations of Met Station, water quality, zooplankton, and zebra mussel abundance data were provided to EPA for its Saginaw Bay ecosystem model calibration.

Toxicokinetics and Bioaccumulation of Organic Contaminants by the Zebra Mussel

(Project Scientist: Landrum)

Assessing the impact of the zebra mussel on the distribution of contaminants in ecosystems dominated by this organism is the goal of this project. The feeding activities of zebra mussels may result in faster deposition of sediments and may also change the composition and mobility of materials on the bottom. The selected chemicals, primarily polychlorinated biphenyls (PCBs) and PAHs, are representative of both their class and the physical and chemical characteristics embodied in the chemicals as model compounds. Compounds from other chemical classes will be employed where specific characteristics will be helpful to determine specific processes or mechanisms of action.

In FY 94, development of analytical methods for PCBs in these different types of samples was begun. The experimental phase of a study on the effects of temperature on the contaminants' accumulation kinetics by the zebra mussel was completed. Analysis of data on the assimilation efficiency of the zebra mussel for several selected compounds from both suspended sediments and algae was completed. The crayfish was identified as a possible link in the zebra mussel food chain, and procedures to work with it were developed, as well as preliminary experiments to determine the uptake and elimination kinetics of several PAHs in the crayfish.

Direct Observations on the Trophic Ecology of *Dreissena* Early Life Stages: The Critical Planktonic Period

(Project Scientist: Vanderploeg)

The pelagic phase (eggs and larvae) of the zebra mussel is a weak link in its life cycle, with mortalities of nearly 100% depending on environmental conditions. This project is (1) observing feeding mechanisms, food choice, and feeding rates of *Dreissena* larvae, (2) determining nutritional requirements of *Dreissena* larvae, and (3) determining the vulnerability of *Dreissena* eggs and larvae to zooplankton.

In FY 94, methods to cultivate zebra mussel larvae were refined with a standard diet (*Chlorella minutissima*) so that larvae may now be routinely reared in the laboratory for research purposes. Methods for conducting predation experiments on larvae in bottles were fully worked out so that combinations of trochophores, veligers, and algae could be simultaneously presented to potential predators at realistic concentrations of predator and prey. Preliminary experiments using these methods were performed.

Long-Term Changes in the Resuspendible Sediments of Saginaw Bay

(Project Scientists: Eadie & Bell)

During feeding, adult zebra mussels capture suspended particulate matter and redeposit it as feces and pseudofeces on the bottom, thereby affecting the composition and mobility of materials in the sediment resuspendible pool in Saginaw Bay and affecting system residence times of particle-associated constituents. Analyzing resuspendible sediments for gross compositional changes, and for nutrients, carbon, and cesium-137 will help to estimate the resuspension flux of these constituents, and will determine the



SCUBA Divers are an important part of sample collection in the Non-Indigenous Species Program.

carbon and nitrogen pathway changes caused by the mussel.

In FY 94, the analyses of stable carbon and nitrogen isotopes in samples collected between 1991 and 1992 were completed, and additional samples were collected for comparison with organic contaminant concentrations. The data revealed that the mass flux of resuspended sediments more than doubled between 1991 and 1992, which supports our hypothesis that the nature and the resuspendibility of bottom sediments will change (increase) in areas heavily infested with the zebra mussel. In addition, the C:N ratio in suspended matter decreased significantly between 1991 and 1992. The C:N ratio is a good indicator of food quality, and the decrease of the ratio in Saginaw Bay indicates a diminished food quality. We attribute this to the increased presence of *Microcystis*, a toxic algae that reappeared with the onset of the zebra mussel infestation.

Effects of the Zebra Mussel on Nutrient Cycling and Lower Food Web Dynamics in Saginaw Bay, Lake Huron

(Project Scientist: Gardner)

By altering the biomass of both phytoplankton and bacteria, which compete for phosphorus, and removing suspended particulates, zebra mussels may affect nutrient cycles and microbial dynamics in an ecosystem. The goal of this project is to (1) determine the direct and indirect effects of the zebra mussel on nutrient regeneration and uptake by various trophic components in the lower food web, (2) determine the effects of the zebra mussel on bacteria, (3) determine how the sources, cycling rates, and fate of labile dissolved organic matter are affected by the presence of the zebra mussel, (4) determine the "nutritional composition" of feces and pseudofeces produced by the zebra mussel, and (5)

compare field observations of standing stocks and process rates with those predicted from bottle and mesocosm experiments.

In FY 94, pelagic bottle experiments to observe the effects of the zebra mussel on lower foodweb and nutrient dynamics were conducted using a series of light (natural) and dark bottle experiments with additions of Nitrogen-15-labeled ammonium and amino acids in the presence and absence of zebra mussels. Results indicate that the zebra mussel may substantially affect bacterial and nutrient dynamics by changing the nature of organic substrates that are available to the bacteria. It was again observed that zebra mussel activity was substantially decreased when the blue-green alga, *Microcystis*, became dominant. Benthic chamber experiments to observe the effects of the zebra mussel on benthic nutrient dynamics and on nutrient regenera-

tion rate ratios were initiated at one field site. Contrary to our expectations, denitrification rates were very low at this location.

Metabolic Physiology of the Zebra Mussel

(Project Scientists: Nalepa)

Although information is available from Europe about biological and ecological characteristics of the zebra mussel, little is known about its physiological characteristics or variation in its biochemical content. Such data are important as indicators of the relative health of the population and may provide an understanding of fluctuations in the populations. Objectives of this project are to determine (1) seasonal oxygen consumption and nitrogen (ammonia) excretion of zebra mussels collected from Lake St. Clair, and (2) lipid content and C:N ratios of soft tissue

from zebra mussels collected from Lake St. Clair and Saginaw Bay. Lipid, carbon, and nitrogen content, and the amount of soft body tissue per unit length are determined for mussels of different sizes (as measured by shell length).

During FY 94, another survey of the distribution and abundance of native mussels (*unionids*) and zebra mussels in Lake St. Clair was conducted. Surveys of the zebra mussel population document changes in numbers over time and determine if changes in the metabolic physiology of the individual are reflected at the level of the population. Surveys of the native mussel population reveal that the native mussel population of Lake St. Clair has been decimated by encroachment of zebra mussels and within a few years, the native mussels will be completely eliminated from the lake.

CLIMATE VARIABILITY AND GLOBAL CHANGE IN LARGE LAKES

The Great Lakes are excellent sites for climate change research because of the existence of measurable physical, biological, and chemical signals, the existence of long-term records, ongoing physical process studies, and the importance of resources (a multibillion dollars port and commercial fishery, fresh drinking water for a large segment of the U.S. population, a multibillion dollar commercial transportation waterway, etc.). Large lakes are "closed systems" with boundaries on spatial scales that make them more tractable for study than the oceans. Many of the environmental situations that make some of the oceanic systems desirable for study of climate change are also present in the Great Lakes and can be studied with smaller logistical budgets. This program combines several projects that examine the potential effects of climate change on the Great Lakes water resources and ecosystem.

Effect of Climate Change on Large-Lake Ice Cycles

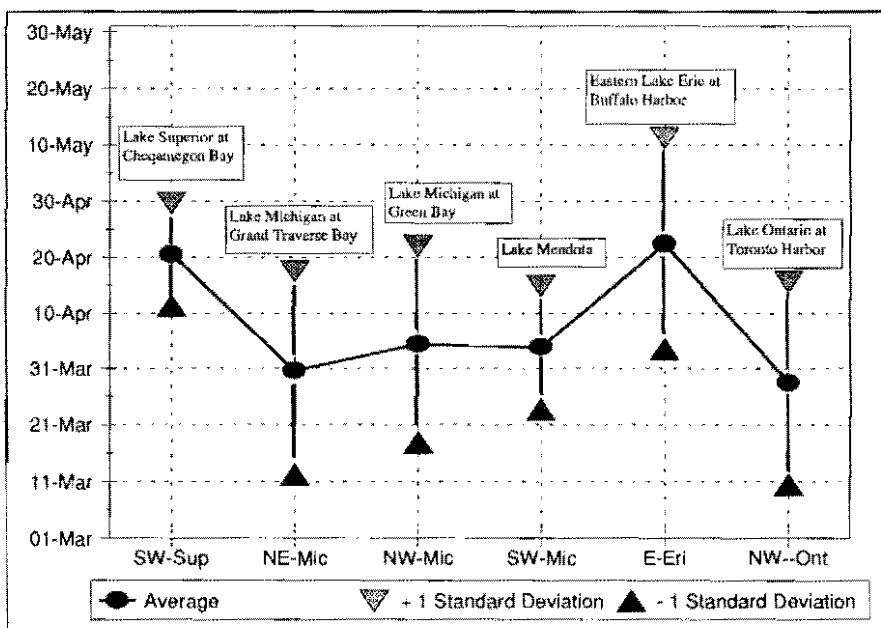
(Project Scientist: Assel)

The duration and extent of ice cover on the Great Lakes have a major impact on the economy of the region by impeding commercial navigation, interfering with hydropower production and cooling water intakes, and damaging shore structures. The ice cover also has an impact on the water balance of the lake by affecting lake evaporation and other heat and momentum transfers, and impacts the biology and chemistry of the lakes, which are affected by the length and extent of ice cover. Climate change associated with global warming will possibly affect the ice cover, which in turn will

affect other physical, chemical, and biological processes. Objectives of this project include (1) developing models to better simulate the seasonal cycle of ice formation and loss on the Great Lakes, (2) estimating the Great Lakes ice cover for past winters, and (3) providing historical information on ice cover trends, cycles, and other variations that will be useful in placing the ice cover of the 1990s and beyond in historical perspective.

In FY 94, freeze-up and/or ice loss dates from five bay and harbor sites on the Great Lakes were analyzed to identify variation and trends in these ice event dates over the past 170 years. The Great Lakes ice cover during the 1993-94 winter was unusually extensive because of unusually low air tem-

Variation in long-term average ice loss dates.



peratures. Data were obtained and compiled from the NOAA Climate Analysis Center in Camp Springs, Maryland, the NWS Forecast Office in Cleveland, Ohio, and the National Ice Center, in Suitland, Maryland, for analysis of the atmospheric circulation associated with the below-normal air temperatures and above-normal ice cover, and to compare with data from previous winters.

Thermal Structure Monitoring for Climate Change

(Project Scientist: McCormick)

The main objectives of this project are (1) to develop improved climatological information (by means of observations, new instrumentation, and improved analysis) on the distribution and variability of coastal and offshore water temperatures and study their dependence on meteorological and hydrological forces, with emphasis on potential changes in climate, and (2) to concurrently provide data for improving numerical models that can simulate and predict the thermal structure in the lakes.

In FY 94, a surface temperature mooring was successfully recovered, its data archived, and another deployed to test new data loggers. Two subsurface moorings, one with current meters and one with thermistors, were also recovered and redeployed. The data storage unit in the subsurface thermistor mooring had a unexplained data gap of several months during the fall and winter. Water temperature data records were obtained from Erie, Pennsylvania; Put-In-Bay, Ohio; Sandusky Bay, Ohio; Tawas City, Michigan; Bay City, Michigan; Milwaukee, Wisconsin; Muskegon, Michigan; St. Joseph, Michigan; Green Bay, Wisconsin; and Sault Ste. Marie, Michigan. Quality control and editing of these data were completed.

Impacts of Climate Change on the Hydrology of the Great Lakes

(Project Scientist: Croley)

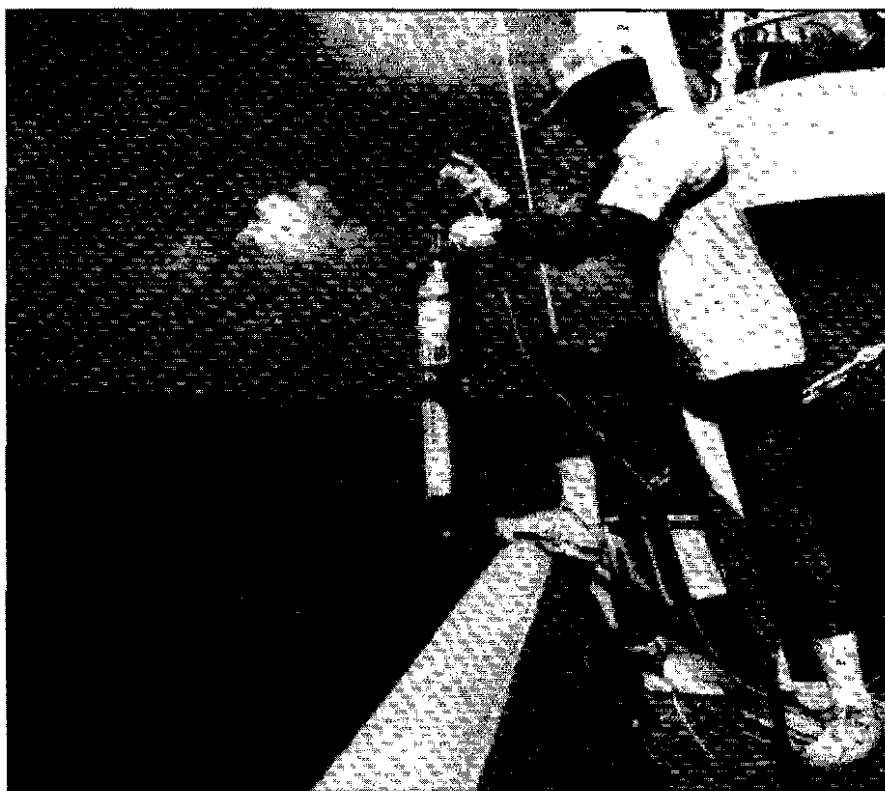
The primary goal of this task is to determine potential impacts of future climate change on the hydrology of the Great Lakes basin, and specifically on net basin water supplies. Of particular concern is how various climate regimes may affect variability from year to year in net basin supplies and in lake levels.

During FY 94, several climate transposition analyses were performed: datasets were prepared for a modified scenario in which lake effects were included, and the climate from the Mississippi River basin during the recent extreme flooding was transferred for five different periods. The hydrological impacts associated with each of these transformed climates were simulated and used to estimate the resulting lake levels and flows through the connecting channels. The Great Lakes Water Supply Forecast System was transferred to the computers of the Midwest Climate Center, the Army Corps of Engineers, and the New York Power Authority.

NECOP

The Nutrient Enhanced Coastal Ocean Productivity (NECOP) activity is one of a series of NOAA-wide programs dealing with major problems in the coastal ocean. The central hypothesis is that increased nutrient input from the Mississippi River has led to increased productivity, with undesirable consequences. GLERL has been involved in the following studies, which are components of NECOP: Fate and Effects of Riverine (and Shelf-Derived) Dissolved Organic Carbon and Nitrogen on Mississippi River Plume-Gulf Shelf Processes; Retrospective Analysis of Nutrient-Enhanced Coastal Ocean Productivity in Louisiana Continental Shelf Sediments; Buoyancy and Nutrient Exchange in the Mississippi River Outflow Region; and Primary Production and Vertical Flux of Organic Carbon.

During FY 94, analyses were completed for remaining samples and all data were compiled for previous field years for all projects under this program. Principal Investigators (PIs) participated in a NECOP workshop to identify progress and plans for the wrap-up of this program. During FY94, the NECOP program formally went into a synthesis mode; except for some monitoring cruises there was no field work in FY 94. An all-PI Synthesis Workshop was held in Baton Rouge, Louisiana, and all GLERL PIs participated in the presentations; summary papers will be published as a proceedings. In addition, several manuscripts were submitted to an issue of the journal *Estuaries* dedicated to the NECOP program. These papers were published in early 1995. GLERL PIs also co-organized and participated in a special NECOP session at the American Geophysical Union-American Society of Limnology and Oceanography (AGU-ASLO) meeting in San Diego. Some 44 papers were presented, and interprogram communication with the northern Gulf Marine Minerals Management Louisiana Texas Experiment (LATEX) program was established. All of these activities will help in the final development of synthesis papers in FY 96.



NECOP Scientist Alan Bratkovich deploying sampling equipment aboard the NOAA Research Vessel *Malcolm Baldrige*.

COASTWATCH

CoastWatch is a NOAA-wide program within the Coastal Ocean Program (COP). As a CoastWatch Regional Site, GLERL is establishing operations of the Great Lakes Regional National Ocean Communications Network (NOCN) Node (RNN), identifying regional CoastWatch users and their NOAA data needs, and supplying useful products to participants in the Great Lakes CoastWatch Program.

Great Lakes CoastWatch and NOAA Ocean Communications Network

(Project Scientist: Leshkevich)

The objectives of this task are to (1) establish operations of the Great Lakes RNN, (2) identify regional CoastWatch users and supply their NOAA data needs, and (3) research and develop related CoastWatch data products and uses specific to the Great Lakes region.

In FY 94, the Great Lakes CoastWatch node supported 35 users, up from 20 the previous year. Surface temperature, winds, Great Lakes marine observations, and water level data were provided routinely as CoastWatch products.

Great Lakes CoastWatch Product Development and Research

(Project Scientist: Leshkevich)

The objectives of this task are to (1) evaluate and help validate Great Lakes CoastWatch products, (2) provide input to the National Environmental Satellite, Data, and Information Service (NESDIS) for product needs and development, and (3) research and develop related products and uses specific to the Great Lakes region using CoastWatch data.

In FY 94, a synthetic aperture radar (SAR) application demonstration and SAR ice field work were completed.

NEARSHORE PROCESSES

Wind and waves are primary driving forces for water movements in the oceans and lakes, and they are major factors in determining nearshore hydrodynamics. Understanding nearshore processes will enable the development of models to identify, forecast, and assist in managing or mitigating nearshore water quality and natural resource problems. The specific scientific objectives of this program are to (1) synthesize the results of research on nearshore hydrodynamics, biological processes, and water chemistry of the nearshore region and apply them to practical problems of coastal environmental management and planning, and (2) sponsor basic and applied research into critical coastal environmental problems.

Dynamics of Nearshore Fronts and Plumes

(Project Scientist: Bratkovich)

Coastal fronts and buoyant plumes are two related hydrodynamic phenomena found in nearshore waters. These features can have a variety of ecological impacts, including the deterioration or enhancement of coastal water quality. The objectives of this project are to (1) acquire data on nearshore fronts and plumes off designated study areas chosen for comparative purposes, (2) develop paradigms and models of the underlying kinematic, dynamic, and ecological patterns, and (3) gather, organize, and analyze historical data pertinent to meteorological forcing and limnologic responses.

In FY 94, field studies in the vicinity of Milwaukee, Wisconsin (western Lake Michigan), and Grand Haven, Michigan (eastern Lake Michigan), were completed. The use of a new remotely operated vehicle (ROV) was evaluated. The ROV was very useful for inspecting instrumented moorings under all weather conditions. Under calmer conditions, it was tested for use as a maneuverable data acquisition platform for environmental sensors. FORTRAN code for simulation of the thermal bar was developed as part of a Ph.D. dissertation effort at the University of Michigan.

Current Measurements in the Nearshore Milwaukee Area

(Project Scientist: Miller)

This project involves a sequence of field measurements designed to characterize the three-dimensional structure of physical and biological fields in

the nearshore region of Milwaukee, Wisconsin and determine the interaction between nearshore and offshore areas.

In FY 94, a National Data Buoy Center (NDBC) buoy was deployed near Milwaukee Harbor in western Lake Michigan, and a current meter mooring was deployed near the NDBC buoy. Three additional current meter moorings were deployed across the lake, and meteorological data from land stations were obtained and archived.

Nearshore Hydrodynamics and Wind Wave Studies

(Project Scientist: Liu)

The objective of this project is to collect and synthesize wind and wave data from selected nearshore areas of the Great Lakes and, along with model studies, provide improved understanding of the wind-wave coupling.

During FY 94, the GLERL Wave Rider Information Processing System (WRIPS) buoy was deployed near Grand Haven, Michigan to gather wave data in conjunction with the sediment resuspension and frontal projects.

INDEPENDENT RESEARCH PROJECTS

Several independent research projects are also included in the GLERL research program. These projects are considered important to the GLERL mission but do not integrate into one of the coordinated research programs.

Environmental Radiotracers (Project Scientist: Robbins)

This project encompasses studies of diverse aquatic systems and emphasizes the use of radiotracers to identify and model fundamental lake/watershed transport processes. Objectives of the program are (1) to identify principal transport mechanisms in aquatic systems and determine associated space-time scales and rates, (2) to investigate and quantify sediment depositional and geochemical processes, (3) to develop geochronological information from sediment radionuclide profiles for paleolimnological studies, (4) to determine and account for relationships between system loadings and sedimentary records of tracers, contaminants, and other constituents, and (5) to apply techniques, insights, and models arising from radiotracer studies to specific problems of ecosystem dynamics, environmental contamination, and regional effects of climate change.

Six new projects were developed during FY 94: Florida Bay (USGS, St. Petersburg, FL), Lake Michigan (US EPA, Duluth/Chicago), Midwestern Reservoirs (USGS, Reston, VA), The Everglades (South Florida Water Management District, W. Palm Beach, FL), Lake Baikal (Center for Great Lakes Studies, Milwaukee, WI), Terrace Lake (USGS, Atlanta), and Grear Lakes Land Margins (Wisconsin Sea Grant, Madison, WI).

During FY 94, a sediment chronology and history was established for metal and organics contamination of Lake George, a receptor site on the St. Marys river downstream from Sault

Ste. Marie (Michigan/Ontario). The study demonstrates the power of using dated sediment records to chronicle the results of pollution abatement and cleanup of the system.

The dynamic mixing model (DYNMX) was embedded into a multi-parameter optimization scheme to establish vertical sediment transport state variable values. This model is used to reconstruct the history of contamination of aquatic systems from sediment profiles and to assess the impact of contaminants on the behavior of sediment-dwelling animals.

A study of particle-selective redistribution of marine sediments by diffusor and conveyor-belt organisms using radiotracer-doped microcosms and the gamma scan system was completed. This is an EPA-supported collaborative study with Case Western Reserve University. The rate and particle-selective character of sediment feeding by several coastal marine organisms was determined, setting the stage for evaluation of their response to contaminant insults.

A 3-year study was completed on the long-term behavior of Chernobyl fallout radionuclides in water, sediments, and fish in Lake Sniardwy—Poland's largest lake. Results show that even fallout nuclides with long half-lives, such as cesium-137 ($t_{1/2} = 30$ years) were cleansed from the water within a few months after the reactor explosion through attachment to settling particles. However, in Bream, a commercially important fish, some radioactivity persisted for years as a result of frequent resuspension of contaminant-laden sediments into the water of

this shallow lake. Long-term decline in concentrations of cesium-137 are tied to the rate at which the radionuclide is buried below the zone of resuspendable sediments by the addition and mixing of new uncontaminated material.

Geochronological models were developed to interpret U-series radionuclides in Lake Baikal sediments. They demonstrate the utility of the approach for dating sediments back to 1 million years before present and discovered that Uranium is a climate-sensitive tracer of water flow in a freshwater lake. Combined with new measurements of diatom frustule abundance and type, U-series dating has provided a glimpse of planktonic life in the lake during the past 250,000 years. The novel U-species disequilibrium method can be applied to reconstruct the regional climate conditions and provide key data for modeling past global climate change.

The history of the loading of Portage Lake with tailings from copper mining in the Keweenaw Peninsula of Michigan was established. Millions of tons of copper-laden tailings were dumped into or surrounding Torch and Portage Lakes, which are part of the Keweenaw waterway. Tailing material, particularly the fine, copper-rich "slime clay," remains toxic to plankton normally found in the lake. Sediment dating, confirmed by radiometric methods, showed that the rate of tailing accumulation in sediments, corresponded extremely well with the annual production of copper on the Peninsula. In response, the addition rate of planktonic remnants to sediments declined dramatically during the period of active mining. Sediment records show that the discharge of tailings, along with possibly other discharges into the lake, all but wiped out the planktonic life as recorded in sediments. With the cessation of activity and efforts to remediate the tailings impact, plankton remnants are again present in

sediment but not yet up to pre-mining levels. The utility of dated sediments to illustrate biologic responses of an aquatic system to environmental insults as well as the characteristics and degree of recovery of lakes is well-illustrated in this study. This project is a collaborative effort with Michigan Technological University with support from the Great Lakes Protection Fund.

A core was dated from contaminated sediments in Coeur D'Alene Lake, Idaho. This lake receives effluents from upstream mining operations commencing at the turn of the century. Radiometric dating is consistent with placement of the onset of contamination in the sediment record with the establishment of mining activities. The information is used, in part, as a poten-

tial means to determine the role of the mining industry in the contamination of the lake and enlisting its cooperation in remediation efforts. This is a collaborative study with the USGS in Atlanta, GA.

Sediment cores from Florida Bay were collected and demonstrated the possibility of assigning time to sediment layers deposited in this century—a major finding that will enable researchers to reconstruct the history of biological and chemical changes in the system, particularly those related to human activities and their presumed ecological impact on the system. Serious, notable degradation of the bay has occurred during the past several decades including decline in bird and sea animal populations, die-back of sea

Sediment coring in Florida Bay.



grasses (*Thelassia*) and mangroves, and episodes of plankton blooms. Major efforts are currently underway by Federal, state, and academic institutions to understand the causes of degradation and to recommend solutions.

Carbon Biogeochemistry in Lakes and Coastal Ecosystems (Project Scientist: Eadie)

Great Lakes and coastal ecosystems are continually subject to a series of stressors that are transient in nature. These lead to issues such as the biogeochemical response of systems to increased or decreased nutrient loads, man-induced changes in the carbon cycle and climate, and the introduction of toxic contaminants and their effects. This project focuses on these issues through research on processes regulating the major biogeochemical cycles and fluxes with an emphasis on carbon. The long-term goal of this research is to develop a hierarchy of calibrated numerical models of processes regulating the biogeochemical cycle of carbon in the Great Lakes with subsequent applications to coastal ecosystems. Presently we are concentrating on Green Bay, Lake Michigan, which has an extensive trophic gradient. Experiments have been conducted to measure the sediment-water and air-water exchange of inorganic carbon, and a survey of the stable isotopic composition is being conducted. Currently, there are five graduate students at Great Lakes basin universities who are working on components of this overall effort.

Lake Ontario Resuspension (Project Scientist: Hawley)

The occurrence and sources of Mirex, PCBs, and other hydrophobic organic contaminants in Lake Ontario continue to be a concern because of their accumulation in the biota and aquatic food chains. Resuspension of

contaminated sediments, which represent the major repository for such compounds, may be an important process affecting the flux of materials back into the water column and the redistribution of contaminants throughout the lake. A zone of sediment containing very high Mirex and PCB concentrations has been identified in sediments along the southwest coast between the Niagara River and Rochester, NY. This study is designed to characterize the importance of resuspension processes in this zone to the redistribution of sediments and associated contaminants in the lake.

In August 1992, moorings were deployed in 60 m of water to measure near-bottom temperature, current, and suspended sediment concentrations, and to trap particulate matter in the water column. The moorings were retrieved in July 1993 at which time we found that the suspended sediment measurements were made for only 15 days before the instruments failed. Analysis of the data available shows that bottom currents (rather than wave action) are responsible for most of the sediment redistribution, but as yet, we cannot determine if most of the material is resuspended locally or if it is transported from shallower areas nearer to shore.

Nitrogen Dynamics (Project Scientist: Gardner)

Results of this study will (1) provide improved methodologies to measure fluxes of important nitrogen compounds that reflect nitrogen dynamics in lakes, wetlands, or marine coastal regions, (2) identify, quantify, and compare major processes controlling nitrogen regeneration from lake and marine coastal sediments, and (3) identify and quantify major nitrogen regeneration processes in lake and/or marine pelagic waters.

FY 94 included the following accomplishments: (1) a project to examine nutrient transformations and limitation in Florida Bay was initiated. (2) Nutrient fluxes and nitrogen transformation rates including denitrification rates were measured seasonally in Old Woman Creek, Lake Erie. This is a wetland that interfaces agricultural runoff regions to Lake Erie. Autumn denitrification rates were typical of those commonly found in other aquatic ecosystems, but spring rates were high. Our data suggest that denitrification may be an important factor removing available nitrogen from non-point sources in this wetland area. (3) A seasonal study of pelagic nitrogen pools and transformation mechanisms and rates in Lake Michigan was conducted to examine factors controlling nitrogen and lower food web dynamics in large temperate lakes. (4) An improved high performance liquid chromatographic (HPLC) method was developed to simplify the measurement of nitrogen transformation rates in Great Lakes and marine coastal systems. This methodology has been applied to investigations in the Gulf of Mexico, Saginaw Bay, Lake Huron, and Florida Bay.

Lake Circulation and Bottom Boundary Layer Studies (Project Scientists: Saylor & Miller)

The existence of a persistent benthic boundary layer has been documented in the offshore regions of all of the Great Lakes. Although the layer contains only a small portion of the total suspended material found in the lakes, sediment trap studies have shown that the bulk of the mass flux occurs within the bottom 25 m. Results of this study will quantify the distribution of bottom current intensities as functions of space and time in order to parameterize the distribution and frequency of resuspension events.

Current measurements close to the lake bottom were performed in Lake Superior at Gull Island Shoal and in Lake Champlain near Valcour Island. The Lake Superior location is a spawning site for one of only a few remnant stocks of native Great Lakes lake trout. Favorable interactions between the reef materials and bottom currents create ideal trout spawning and nursery conditions. The Lake Champlain location exhibits sediment erosion and transport at frequent intervals in water as deep as 100 m. Currents driven by large amplitude internal waves were identified as the cause of the resuspension events.

Microplankton in the Great Lakes: A Comparative Study of the Laurentian Great Lakes

(Project Scientist: Fahnenstiel)

The microplankton (bacteria, algae, and protists) occupy a key position in the food web of large lakes and may constitute most of the pelagic biomass as well as control carbon and nutrient cycling. Although these organisms occupy a key position, very little is known about the biomass and production of this important taxa. The goal of this project is to examine the dynamics of microplankton including key processes in several large lakes in order to further our understanding of the food web.

GLERL researchers have just completed the second year of a 3-year study to compare food web structure and productivity dynamics of Lakes Huron, Michigan, Erie, and Ontario. This work is supported by GLERL and the National Science Foundation (NSF) and is a cooperative project with researchers from the University of Florida.

The Microbial Food Web in the Great Lakes

(Project Scientist: Fahnenstiel)

In the past few years, aquatic food webs have been discovered to be far more complex than previously thought. The discovery of the microbial food web has forced a revision of contemporary models of plankton dynamics. These new discoveries have changed our ideas of the classic food web to include the recognition that photosynthetic and heterotrophic picoplankton often control whole-system metabolism and nutrient cycling, that pelagic food webs are more complex than previously thought, that a large percentage of primary production is not consumed directly by zooplankton but rather is channeled through a picoplankton-protozoan-crustacean zooplankton link, and that protozoans are an important prey item for crustacean zooplankton. Recently a guide to protozoan communities in the Great Lakes was completed; it will serve to kindle research on microbial food webs in the Great Lakes.

Ecological Monitoring

(Project Scientist: Vanderploeg)

Maintaining long-term data to provide a basis for recognizing and forecasting changes in plankton dynamics due to climate changes is needed because potential change in both absolute temperature and the onset and duration of thermal stratification could lead to substantial changes in Great Lakes ecology. The primary objective of this project is to monitor plankton dynamics to recognize changes due to climate change. Collection of a detailed data set capable of separating

normal seasonal dynamics and year to year variability from long-term changes is necessary to detect climate-driven effects. These data will also be useful for detecting long-term changes due to nutrient loadings, exotic species invasions, fish management, and other general ecological events.

Zebra Mussel Protocol

(Project Scientist: Reid)

A working group of academic and government scientists completed development of "Zebra-Mussel-Specific Containment Protocols." The Protocols document is for use nationally by the research community to help minimize the potential for spread of the zebra mussel through insufficient or careless containment during research activities. The final version was accepted on December 29, 1993 by the Research Protocol Committee of the Aquatic Nuisance Species (ANS) Task Force. Availability of the pre-approved protocol should save considerable time in the proposal approval process within federal agencies requiring the use of approved protocols.

FACILITIES AND SERVICES

Computer Facility

The GLERL computer facility can be best described as a Local Area Network (LAN) of distributed computing resources. This network currently consists of 8 VAXs, 10 UNIX/RISC workstations, 6 Macs, and about 80 PCs connected via ethernet. The LAN is connected to the Internet via a router to MichNet.

A variety of scientific applications, including real-time and near real-time data acquisition, data reduction, graphical display, image processing, statistical and mathematical analysis, etc., are accessed by GLERL personnel and collaborators. A full suite of office automation applications are also supported.

GLERL is the Great Lakes Redistribution Node of the National Ocean Communication Network (NOCN), and, as such, makes satellite imagery available to government, private, and academic users throughout the Great Lakes region. GLERL is also a partner in the Great Lakes Commission's Great Lakes Information Network (GLIN).

Library

The GLERL library's program-oriented research collection is maintained in support of the laboratory's research activities. The collection reflects an emphasis on freshwater studies—particularly in the Great Lakes basin. The library currently receives 211 periodical subscriptions. Books dating from 1980 onward, as well as many earlier books, are included in the online union catalog by Online Computer Library Center, Inc (OCLC). These books are also reflected in the NOAA Library

GLERL's research facility contains 17 laboratories equipped with general laboratory equipment. In addition, GLERL has a stable isotope mass spectrometer (SIMS), a fully equipped radiotracer laboratory, several gas chromatographs and liquid scintillation counters, a high pressure liquid chromatography system, a multi-channel Coulter Counter, growth chambers and incubators, stereo and inverted microscopes, and a fully equipped multi-purpose epifluorescence microscope. GLERL also has high speed microcinematography equipment located in a temperature-controlled environmental chamber which is maintained for conducting experiments and growing biological cultures at low temperatures. A new Geographic Information System Laboratory was established at GLERL during FY 93.

Catalog available via remote online access, commercial CD-ROM, and the library's public access catalog workstation. Interactive searches may be made of library records using Boolean search options and displays in various formats. GLERL library facilities are open to the public for reference use during normal business hours.

Library staff maintain the collection and provide library and information retrieval services. Special retrieval services are provided when the collection does not meet the needs of individual scientists. Services include acquisition, circulation, document delivery, interlibrary loan, reference, and online/CD-ROM information retrieval.

During FY 94, library public access equipment was upgraded, and several years of GLERL reprints were cataloged into a PC based database.

The CD-ROM workstation was upgraded and additional CD-ROM databases were acquired making a total of 21 titles supporting both bibliographic and reference needs. All back year holdings (568 reprints) of the library's collection of GLERL reprints,

Library holdings include 6,069 periodical volumes, 8,272 books/technical reports, and 233 dissertations covering the subject areas of climatology, contaminant organics, hydraulics, hydrology, ice, limnology, mathematical models, meteorology, nutrients, oceanography, sediments, and wave motion.

If you would like to be added to GLERL's mailing list, or would like additional information on GLERL's research, please write to:

Publications Office
NOAA/GLERL
2205 Commonwealth Blvd.
Ann Arbor, MI 48105

written by GLERL/CILER authors at the laboratory, were sorted and cataloged into a personal computer database. The new database system permits both quick access for researchers using printed indexes and computer access when detailed searching is required.

The GLERL library is a member of the Michigan Library Consortium (MLC), Washtenaw-Livingston Library Network (WLLN), Federal Library and Information Network (FEDLINK), NOAA Library and Information Network (NLIN), and the OCLC.

Information Services

■ Publications Unit

The Publications Unit staff are responsible for providing editorial and publications support to the scientific staff, for preparing and distributing GLERL publications, and for responding to publications and information requests from the public. They also produce and update reports, brochures, and displays concerning GLERL's work.

Research products generated during FY 94 include 49 scientific articles, reports, and books and 50 formal presentations. Requests for information this fiscal year came from 44 different countries. In addition, requests were

answered from U.S. universities, schools, media, state, local, and U.S. government agencies as well as from private citizens in both the U.S. and foreign countries. There were 2,209 items mailed in response to information requests.

The Publications Unit maintains a mailing list for distribution of GLERL publications. The GLERL Yearly Report and the Six Month Update are automatically distributed according to this mailing list. All new publications, including NOAA reports, journal articles, and books, are added to our six-month update listing of new publications to keep our users informed of GLERL's latest product releases.

The Publications Unit has completed its new bibliographic database system that has a full text search capability to assist Publications Unit staff in identifying and locating information in response to requests. In the future, this new database will become available to the public on the GLERL gopher server.

Vessel Operations

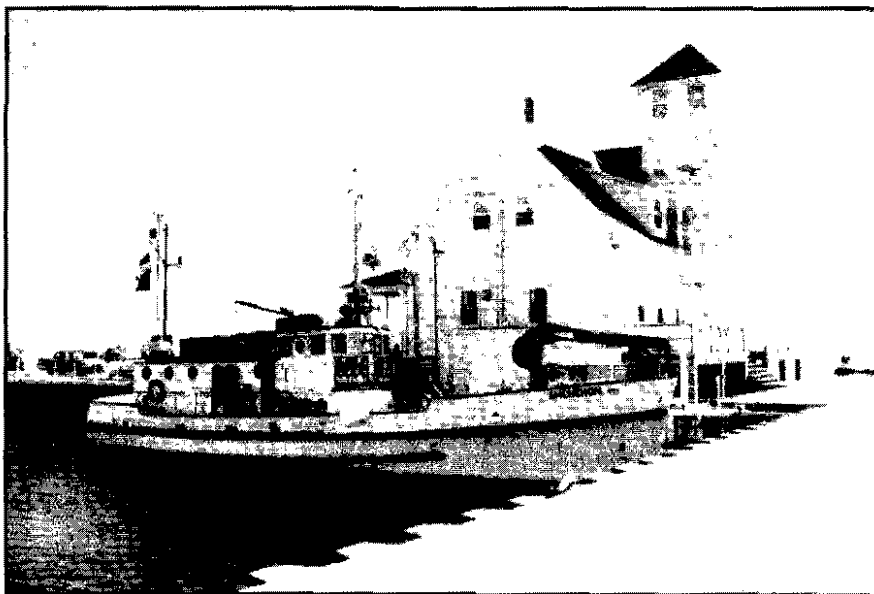
■ Muskegon Facility

The GLERL Vessel Operations Facility is located in Muskegon, MI at a former Coast Guard base and includes three buildings and research vessel dockage adjacent to the main building.

During FY 94 a lake-side research laboratory was established: one building was converted to a laboratory, offices, and research storage, and two research personnel were transferred from Ann Arbor to conduct biological monitoring studies. Because a continuous supply of lake water is available from the adjacent Lake Michigan, some studies can now be conducted that are not feasible at the laboratory in Ann Arbor.

There is dockage for the R/V *Shenelon* and a smaller research launch in the Coast Guard mooring basin adjacent to the main building. A lease for 100 feet of dockage has also been obtained from the Corps of Engineers at the Government Mooring Basin approximately 0.3 mile from the main building.

GLERL's Lake Michigan Field Station located in Muskegon.



■ Research Vessels

The Research Vessel *Shenehon* is owned and operated by GLERL. The *Shenehon* is based at the Vessel Operations Facility, Muskegon, MI and is the primary platform used in support of GLERL's open lake field investigations. The *Shenehon* was built in 1953. It is 65.6 feet long, with a 6.5-foot mean draft, a 700-nautical-mile cruising range, and a 10-knot cruising speed. Navigational equipment includes a Sperry Gyrocompass, Raytheon Radar, GPS and two LORAN-C positioning systems, Sperry Auto Pilot and a Raytheon Depth Sounder. A 55-channel radiotelephone is available for ship to shore communication. Electrical power is provided by a modern 20-kW, 3-phase Onan generator, and a 30-kW, 3-phase Onan generator. An electro-hydraulic articulated crane is used for deployment and retrieval of water and bottom sediment samplers and heavy instrument moorings. Electrohydraulic winches handle hydrographic wire and multiconductor cable for sample casts and *in situ* measurements of water variables. An on-board wet laboratory is available for on-site experiments and sample processing. Scientific equipment includes various sizes of Niskin samplers, reversing thermometers, bottom samplers, including a small box corer. A data acquisition system records and plots data from a Sea Tech transmissometer which is coupled to an electronic bathythermograph. The system includes equipment to record, process, and plot water temperature data collected using Sippican Expendable Bathythermograph (XBT) probes.

Two small boats are used as auxiliary research platforms. A 23-foot Monark workboat, The *Remorse*, is outfitted as a research launch with navigational and safety equipment and an electric winch and crane. A SeaArk workboat, The *Cyclops*, is 28.5 feet in

length, including a 2.5 foot deck extension, and is used primarily for the Non-Indigenous Species Program in Saginaw Bay and in Lake St. Clair. Navigational equipment includes a radar, magnetic compass, a 91-channel radiotelephone, a Loran-C positioning system, a 50-kHz digital depth sounder with digital and video displays, two sounder wells, and an auto pilot. An electric winch and crane is available for deployment and retrieval of sampling equipment. Safety equipment includes an inflatable life raft and an EPIRB (emergency transmitter).

■ Research Support

The majority of the work supported by the *Shenehon*, the *Cyclops*, and the *Remorse* was connected with biological studies in Lake Michigan and in Saginaw Bay. These studies included benthic, planktonic, and bacte-

rial experiments relating to algal growth, zooplankton grazing, food chain transport in the aquatic environment, fate and effects of sediment associated toxic organics, and long-term trends of benthic fauna. Exotic species such as the zebra mussel and *Bythotrephes* continue to be a major part of the studies.

During FY 1994, cruises were made in Lake Michigan, through the Straits of Mackinac, and in Saginaw Bay.

Sediment traps were deployed at eight stations in Lake Michigan to monitor the vertical mass and chemical flux. Instrumented tripods were deployed in Lake Michigan to study bottom currents and the resuspension of sediments.

Current meters and temperature sensors were deployed in Lake Michigan between Muskegon and Milwaukee as part of a nearshore and bottom boundary layer study. Current and tem-

GLERL's Data Collection Equipment

39 AMF Vector Averaging Current Meters

16 Acoustical Releases

7 LORAN Drifter Buoys

10 GPS Drifter Buoys

1 Adamo-Rupp WRIPS Waverider Buoy

6 TR-1 Aanderaa Thermistor String Recorders

7 TR-7 Aanderaa Thermistor String Recorders

5 Marsh McBirney 585 Current Meters

3 Sediment Transport Measuring Tripods

3 ODE EMI Current Meters with Thermistor Strings

1 RD Instruments DR-1200 Acoustic Doppler Current Profiler (ADCP)

2 SC-600 Narrow Band ADCPs

1 SC-600 Broad Band ADCP

10 Sequential Sediment Samplers

2 Meteorological Data Collection Platforms

perature sensors were deployed in the center of the southern basin of Lake Michigan.

The 100-m station off Grand Haven, MI continued to be the site monitored using sediment traps and periodic water and plankton samplings to study the temporal variations in water quality, and the vertical mass and chemical flux as determined by samples from the traps. Particular emphasis was placed on carbon pools and the rates of transfer. Several cruises were made using both the *Shenelon* and the *Cyclops* in connection with studies of frontal processes off Grand Haven and Muskegon, MI.

Three new sediment traps of GLERL design for collecting sequential samples in the water column were successfully tested in Lake Michigan and redeployed to collect samples over a period of 1 year. Two sequencing traps of Pacific Marine Environment Lab (PMEL) design were deployed over the winter in Lake Michigan at the 100-m station. These traps were recovered, serviced, and redeployed for the 1994-1995 winter and spring periods.

GLERL vessels were again provided for studies conducted by the University of Michigan, and for classes from the Churchill School in Muskegon, MI. The *Remorse* was provided to the NOS for the expansion of their Mussel Watch Program in the Great Lakes. Their program includes monitoring 21 zebra mussel watch sites in Lakes Michigan, Huron, Erie, and Ontario.

Marine Instrumentation Laboratory

The Marine Instrumentation Laboratory (MIL) staff select, calibrate, repair, and, when necessary, adapt or design instruments to collect data in the lakes and their environs. Engineers and technicians in this unit work closely with GLERL researchers to ensure that instruments are compatible with their needs. They also participate in field experiments by providing support for the deployment and retrieval of field equipment, assistance with the collection of samples and data, and in-field maintenance or repair of equipment.

In FY 94, MIL staff prepared and developed equipment for use in southern Lake Michigan, Green Bay, WI, Saginaw Bay, Lake Champlain, NY, Cape Hatteras, NC, and the Gulf of Mexico in support of National programs such as NECOP and the South Atlantic Bight Recruitment Experiment (SABRE) as well as EPA contracts and nearshore hydrodynamics.

A meteorological data collection platform was installed on the Gravelly Shoal Lighthouse located in Bay City, MI and serviced by MIL to provide real-time meteorological data through the GOES satellite system for the zebra mussel experiments being conducted in Saginaw Bay.

Geographic Information System Laboratory

The development of GLERL's Geographic Information System (GIS) laboratory was initiated in the fall of 1992. The laboratory is composed of commercial GIS and relational database software resident on a UNIX workstation, 10 GB of external disk storage, a high accuracy digitizer, a color thermal wax transfer printer, and a CD-ROM drive. A full-time GIS specialist operates the system.

In support of GLERL's hydrologic research, detailed topography, soils, land use/land cover, and hydrography have been obtained for the Great Lakes region.

In support of the Great Lakes Ice Cover Data Rescue Program, Great Lakes ice charts are being digitized. Along with ice cover extent, ice characteristics such as type and thickness are being preserved. The GIS has been used to produce maps of monthly and annual thermal fluxes for each of the Great Lakes, to provide conversion factors between the irregular shaped areas of the lumped parameter runoff model and the 40 km gridded RAMS atmospheric model to enable linkage of these models, and to develop various graphical products in support of technical papers and presentations.

OUTREACH

The GLERL mission includes the development of environmental information, data, and service tools for users in government and private organizations. Staff participation on boards, commissions, task forces, and committees helps to identify environmental information needed by our users and to guide our research focus and the development of usable products. During FY 94, GLERL staff participated as members of the boards, committees, and task forces listed below.

International Joint Commission

- ◆ Council of Great Lakes Research Managers (A. Beeton, member)
- ◆ Great Lakes Research Inventory (A. Beeton)
- ◆ Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data
 - Hydrometeorology and Modeling Subcommittee (T. Croley II, D. Lee)
 - River Flow Subcommittee (F. Quinn)

Other interagency, professional society, and international activities:

- ◆ American Institute of Hydrology - Michigan State Section (T. Croley II, President)
- ◆ American Society for Testing and Materials Sediment Toxicity Subcommittee (P. Landrum)
- ◆ American Society for Limnology & Oceanography
 - Editorial Board (H. Vanderploeg)
 - Finance Committee (A. Beeton, Chair)
- ◆ American Society of Civil Engineers
 - Task Committee on Hydrodynamics of Lakes (P. Liu)
- ◆ American Water Resources Association - Michigan State Section (D. Lee, President)
- ◆ *Chemosphere*, Board of Editors (P. Landrum)
- ◆ Dept. of Environmental Toxicology (P. Landrum, Adjunct Professor)
- ◆ Critical Reviews in Environmental Science and Technology, Editorial Board (P. Landrum)
- ◆ Eastern Snow Conference Steering Committee (D. Norton)
- ◆ Environmental Reviews, Assoc. Editor (A. Beeton)
- ◆ German Marshall Fund of the United States, Fellowship Program (F. Quinn)
- ◆ Great Lakes Commission
 - Drought Management and Great Lakes Water Levels Task Force (F. Quinn)

- Great Lakes Panel on Non-Indigenous Species (T. Nalepa, A. Beeton)
- Great Lakes Speakers Bureau Directory (F. Quinn)
- Task Force on Emergency Preparedness (D. Reid)
- Ecosystem Charter Committee (A. Beeton)
- Observer delegate (A. Beeton)
- Great Lakes Information Network (GLIN) (L. Herche)
- ◆ Great Lakes Protection Fund
 - Technical Advisory Committee (A. Beeton)
- ◆ International Association for Great Lakes Research (IAGLR)
 - Board of Directors (M. Quigley, G. Fahnenstiel)
 - IAGLR Membership and Endowment Committee (M. Quigley, Chair; B. Eadie, Liaison with SIL)
 - *Journal of Great Lakes Research* (F. Quinn, D. Schwab, T. Nalepa, P. Landrum, Associate Editors)
 - Publications and Awards Committees (G. Fahnenstiel)
- ◆ International Association of Theoretical and Applied Limnology (A. Beeton, U.S. Representative)
- ◆ International Great Lakes - St. Lawrence Ice Information Working Group (R. Assel, U.S. Co-chair; D. Norton, G. Leshkevich)
- ◆ Interagency Non-Indigenous Species Research Protocol Committee (D. Reid, Member)
- ◆ Journal of Sedimentary Research (N. Hawley, Associate Editor)
- ◆ Kent State University - Ph.D. Committee (W. Gardner)
- ◆ Michigan Sea Grant Research Advisory Committee (J. Saylor, A. Bratkovich)
- ◆ Michigan State University - Ph.D. Committee (B. Eadie)
- ◆ Midwestern Climate Center
 - External Advisory Panel (T. Croley II)
 - Research Review Committee (T. Croley II)
- ◆ Mississippi-Alabama Sea Grant Program reviewer (A. Beeton)
- ◆ National Research Council
 - Postdoctoral Program (A. Beeton, W. Gardner, H. Vanderploeg, P. Landrum, A. Bratkovich, D. Schwab)
- ◆ National Sea Grant Zebra Mussel Review Panel (T. Nalepa)
- ◆ National Sea Grant Chesapeake Bay Review Panel (P. Landrum)
- ◆ National Science Foundation
 - Steering Committee, Great Lakes Coastal Ocean Program (B. Eadie, G. Fahnenstiel)
 - Coastal Ocean Program Review (B. Eadie)
- ◆ NOAA Climate and Global Change Program
 - Technical Advisory Committee (H. Vanderploeg)
- ◆ NOAA Coastal Ocean Program
 - Planning Workshop (B. Eadie, W. Gardner, N. Hawley, J. Saylor)
 - Great Lakes Forecasting System (D. Schwab, M. McCormick)
 - Coastal Hazards Component (D. Schwab)
 - NOAA/ERL Satellite Requirements Committee (G. Leshkevich)
 - NOAA Mississippi River Plume/Gulf Shelf Region Research Planning Workshop (Gardner, Fahnenstiel)

- NOAA NECOP Technical Advisory Committee (B. Eadie, W. Gardner)
- CoastWatch Management Team (G. Leshkevich)
- CoastWatch Program (G. Leshkevich, D. Schwab, G. Spalding)
- CoastWatch SAR Implementation Team (G. Leshkevich)
- ◆ NOAA ERL Technical Committee on Computer Resources (G. Spalding)
- ◆ NOAA Measurement Technique Development/Ocean Acoustic Techniques and Climate Change Committee Member (M. McCormick)
- ◆ NOAA Network Operations Group (G. Spalding)
- ◆ NOAA/NOS Thunder Bay Marine Sanctuary (D. Reid, Liaison)
- ◆ NOAA/NURP University of Connecticut/Avery Pt. Center
 - Critical Body Burden Project (P. Landrum)
 - Proposal Review Panel (T. Nalepa)
- ◆ NOAA Sea Grant Zebra Mussel Project (P. Landrum)
- ◆ NOAA Technical Subcommittee, New Bedford Superfund Action (B. Eadie)
- ◆ Ohio Sea Grant
 - Ph.D. Committees (D. Schwab)
- ◆ Rouge River Wet Weather Demonstration Project, GIS Technical Advisory Group (D. Lee)
- ◆ State of Michigan, Department of Natural Resources
 - Great Lakes Information System Technical Advisory Committee (A. Beeton)
 - Michigan Great Lakes Fund (A. Beeton)
 - Saginaw Bay National Water Quality Initiative
 - Program Advisory Committee (D. Reid)
 - Technical Advisory Committee (W. Gardner)
- ◆ State University of New York (SUNY) Buffalo, Great Lakes Programs
 - Advisory Board (F. Quinn)
- ◆ The Ohio State University, Dept. of Entomology (Adjunct Associate Professor, P. Landrum)
- ◆ The University of Michigan
 - Cooperative Institute for Limnology and Ecosystems Research (CILER) Board of Directors (A. Beeton); Council of Fellows (A. Bratkovich, T. Croley II, B. Eadie, P. Landrum, M. McCormick, T. Nalepa, F. Quinn, D. Reid, D. Schwab, H. Vanderploeg)
 - Biological Station Executive Committee (A. Beeton)
 - Ph.D Committees (A. Beeton, A. Bratkovich, G. Fahnenstiel, J. Saylor, B. Eadie, H. Vanderploeg)
 - School of Natural Resources, Adjunct Prof. (J. Robbins, G. Fahnenstiel)
 - School of Public Health, Dept. of Environmental Health, Adjunct Prof. (A. Beeton, P. Landrum)
 - Task Force on Environmental Studies (A. Beeton)
- ◆ Thurston Nature Center Advisory Committee (A. Bratkovich)
- ◆ U.S. Army Corps of Engineers
 - Mussel Work Group - Navigation Study (T. Nalepa)
- ◆ U.S.-Canada Ice Information Working Group
 - Great Lakes Ice Issues Subcommittee (R. Assel, U.S. Co-chair)

- ◆ U.S. Coast Guard
 - Cargo Sweeping Scientific Steering Committee (D. Reid, Chair; P. Landrum, member)
- ◆ U.S. Department of Commerce
 - NOAA-Representative to Region 5 Regional Response Team (D. Reid)
 - U.S.-Canada Joint Response Team (D. Reid)
- ◆ U.S. Department of Energy, Ocean Margins Program
 - Review Panel (B. Eadie)
- ◆ U.S. Department of State
 - Cooperative study of Lake Maracaibo with the Institute for the Control and Conservation of Lake Maracaibo
 - Cooperative study on Chernobyl Fallout in Masurian Lakes, Poland (J. Robbins)
 - Russian cooperative research programs (A. Beeton)
- ◆ U.S. Environmental Protection Agency
 - Binational Executive Committee/USA-Canada (A. Beeton)
 - EMAP - Great Lakes Research Committee (T. Nalepa)
 - Lake Michigan Mass Balance Program
 - Biota Group (G. Fahnenstiel)
 - Technical Advisory Committee (B. Eadie)
 - Policy Committee (A. Beeton)
- ◆ U.S. Soil Conservation Service (A. Beeton, Technical Advisor)
 - Muskegon Lake Public Advisory Council (G. Fahnenstiel)
- ◆ University of Minnesota - Ph.D. Committee (B. Eadie)
- ◆ University of Nebraska - Ph.D. Committee (B. Eadie)
- ◆ University of Wisconsin - Ph.D. Committee (B. Eadie)
- ◆ University of Wisconsin Sea Grant Institute (A. Beeton, Site Team Member)
- ◆ Zebra Mussel Coordination Committee (A. Beeton, Chair)

International Activities

Cooperative research is often performed with scientists from around the world. In FY 94, this included scientists from Canada, Germany, Russia, Poland, Finland, China, Mexico, and Venezuela.

Visiting Scientists

- Russian Academy of Sciences, St. Petersburg, Russia (Soros Foundation Fellow)
- Rzeszow University of Technology, Rzeszo'w, Poland
- Fulbright Visiting Scholar
- Institute for the Control and Conservation of Lake Maracaibo, Venezuela
- People's Republic of China
- State University of New York

Cooperative Research was performed with the following organizations:

- Argonne National Laboratory
- Canadian Centre for Inland Waters

- Canadian Centre for Remote Sensing
- Canadian Climate Center
- Canada Hydrographic Service
- Canadian National Hydrology Research Institute
- Case Western Reserve University
- Center of Limnology, University of Wisconsin, Madison
- Clemson University
- Illinois State Water Survey
- Kent State University
- Michigan State University
- Middlebury College and Lamont-Doherty
- Midwest Climate Center
- NASA/Goddard
- Naval Ocean and Atmospheric Research Lab (NOARL)
- NOAA AOML
- NOAA ERL Air Resources Laboratory, Silver Spring, MD
- NOAA/NESDIS
- NOAA National Geophysical Data Center
- Ohio State University
- Ohio Sea Grant
- St. John Associates, Beltsville, MD
- State University of New York - Stony Brook
- Stockholm University, Sweden
- Texas A&M University
- USSR Academy of Sciences
- U.S. EPA, Environmental Monitoring Systems Laboratory
- U.S. EPA, Environmental Research Laboratories, Duluth, MN and Grosse Ile, MI
- U.S. EPA, Great Lakes National Program Office
- U.S. Fish and Wildlife Service
- U.S. Geological Survey, Water Resources Division, Madison, WI
- University of Michigan
- University of Munich, Germany
- University of Texas at Austin
- University of Waterloo, Ontario, Canada
- University of Wisconsin-Milwaukee on Yellowstone Lake and Green Bay
- University of Wisconsin on Nearshore Hydrodynamics
- Weber State University

GLERL also:

- Provided statistical consulting to scientists from The University of Michigan and The University of British Columbia.
- Continued coordination with the Midwestern Climate Center and the Illinois State Water Survey to develop a Midwestern Climate Information System (MICIS).
- In cooperation with researchers from Ohio State University, NOAA Center for Ocean Analysis and Prediction (COAP), and the National Weather Service, developed the Great Lakes Forecasting System, a prototype coastal ocean prediction system for the Great Lakes.
- Served on a review panel for the Department of Interior's Natural Resource Damage Assessment Model for the Great Lakes, a 2-year effort to develop a computer program for assessing financial damages for environmental accidents on the Great Lakes.
- Participated in Cooperative Student Programs with The University of Michigan and Eastern Michigan University.
- Guided students on tours of our facility and gave briefings of GLERL activities.
- Muskegon Vessel Operations Facility used in Muskegon Area Labor Day Telethon for Muscular Dystrophy.
- Organized and convened a joint GLERL-CILER workshop on "The Environmental Implications of Cargo Sweeping on the Great Lakes" to assist the U.S. Coast Guard in developing regulations affecting the shipping industry (D. Reid, P Landrum).
- Participated in a local initiative to develop environmentally sound management approaches for the local Miller's Creek Watershed; in conjunction with ERIM, Univ. of MI, National Sanitation Foundation, Parke-Davis, local neighborhood organizations, and the Ann Arbor Public Schools (D. Reid, C. Sellinger).
- Shared Gamma Scan automated instrumentation with scientists at Case Western Reserve University in Cleveland.
- Hosted the White House Interagency Ecosystem Management Team in cooperation with the U.S. Geological Survey, the National Bureau of Standards, and the Great Lakes Commission.
- Hosted the Government Accounting Office's Ecosystem Management Team in cooperation with the National Biological Service and the U.S. Geological Survey.
- Organized and hosted the 51st meeting of the Eastern Snow Conference (D. Norton, R. Assel).

Meetings and Presentations

An integral part of the scientific development of GLERL staff is attendance and participation in scientific and technical meetings. During FY 94, GLERL sponsored in-house seminars as part of the GLERL Informal Seminar Series and the Great Lakes Seminar Series. Our staff made 50 presentations concerning GLERL's work at public and professional meetings.

Technology Transfers

GLERL staff responded to 744 requests for information during FY 94 and provided more than 2,209 items to service those requests. GLERL's mailing list contains 334 subscribers serving people in 44 countries. Requests are received from private citizens, foreign and U.S. universities, foreign and U.S. government agencies, and private industry. Many of the products that GLERL produces and distributes involve a transfer of both technology and data. During FY 94, GLERL's outreach of this nature involved the transfer of the following:

Great Lakes Freezing Degree Day Ice Cover Model

- Canadian Climate Center

Plans for construction of Photosynthetron

- Kent State University

Great Lakes CoastWatch Data Users

- Argonne National Laboratory
- Bloom Trail High School
- CAPAC Community Schools
- Eastern Michigan University
- Environmental Research Institute of Michigan (ERIM)
- Lake Superior Center, Duluth, MN
- McMaster University, Environmental Hydraulics Program
- Miami University, Department of Geography
- Michigan DNR Forest Management Division
- Michigan State University, Michigan Sea Grant Extension—Marquette
- Michigan State University, Michigan Sea Grant Extension—Grand Haven
- Michigan State University, Michigan Sea Grant Program
- Michigan State University, Center for Remote Sensing
- Michigan Technological University, Lake Superior Ecosystems Research Center
- Michigan Technological University, Dept. of Civil and Environmental Engineering
- Ohio State University
- U.S. Army Corps of Engineers, Chicago District
- U.S. EPA, Environmental Monitoring Systems Lab
- U.S. EPA, Great Lakes National Program Office
- U.S. Department of Interior, Hammond Bay Biological Station
- U.S. Department of Interior, National Fisheries Research Center, Great Lakes
- U.S. Department of Interior, USGS, Water Resources Division
- U.S. Department of Interior, Lower Great Lakes Fishery Resources Office
- University of Florida, Department of Fisheries and Aquatic Sciences
- University of Illinois, Illinois-Indiana Sea Grant Program
- University of Michigan, Department of Biology
- University of Wisconsin-Madison (Wisconsin Sea Grant Program)
- University of Wisconsin-Milwaukee, Center for Great Lakes Studies

Hydrologic Response Model

- Ohio State University

Net Basin Supply Forecast Package

- U.S. Army Corps of Engineers, Detroit District
- Midwestern Climate Center

Great Lakes Ice Cover/Water Temperature Animation

St. Lawrence Seaway Development Corp.	Nature Conservancy	Natural Resources Inst.-U. K.
MacLaren Plansearch	Beak Consultants Ltd.	GeoMatics Intl., Inc.
Rust E&I	Volpe Center	Montgomery Watson Consult.
DePaul Univ.	SUNY Buffalo	SUNY Brockport
SUNY Genesco	Cornell Univ.	Univ. of Illinois
Univ. of Wisconsin	Univ. of Michigan	Univ. of North Carolina
Univ. of Chicago	Mich Tech. Univ.	Michigan Sea Grant, Marquette, MI
Michigan State Univ.	Oakland, Univ.	Ohio State Univ.
Univ. of Colorado	Parcell Middle School	Mail St. Element. School, NY
Great Neck Public School	Naval Polar Oceanog. Center	U.S. Coast Guard, Cleveland
U.S. EPA	U.S. Dept. of Interior	U.S. Fish and Wildlife
U.S. Army CRREL	U.S. Army Corps of Engineers	U.S. Geological Survey
Argonne National Laboratory	NOAA Educational Affairs	National Weather Service
Illinois State Water Survey	Lake Superior Centre	Michigan Dept. Natural Resources
Wiscon Dept. Natural Resources	NY State EEC	NY State Parks and Recreation
Milwaukee Metro Sewage District	Univer. Muchen, Germany	Univ. of Waterloo, Canada
McMaster Univ. - Canada	Queen's Univ.-Canada	Environment Canada
Canadian Centre for Inland Waters	Atmos. Environment Serv.	Canadian Coast Guard
Ontario Weather Center	National Water Res. Inst.	St. Lawrence Seaway Authority

Water Resources Simulation Package

- Atmospheric Environment Service (Canada)

Wave Forecast Model

- National Weather Service, Cleveland, OH

"Pathfinder" Trajectory Prediction System

- U.S. Department of the Interior
- U.S. Coast Guard
- McMaster University

Thiessen Weighting Package

- Atmospheric Environment Service (Canada)

Satellite Drifter Programs

- Canada Centre for Inland Waters
- Scripps Institution of Oceanography
- University of Texas

Evaporation and Other Data

- National Weather Service
- University of Wisconsin

GLERL's data gathering equipment and Geographic Information System was shared with:

- The University of Michigan (Center for Great Lakes and Aquatic Sciences; College of Engineering)
- U.S. Army Corps of Engineers
- U.S. Department of the Interior, Fish and Wildlife Service
- Canadian Centre for Inland Waters
- University of Wisconsin
- University of S. Mississippi
- Middlebury College
- U.S. Department of Interior, National Biological Service
- U.S. EPA, Environmental Monitoring Systems Laboratory, SUNY Stony Brook
- GLERL-designed photosynthetron was shared with Kent State Univ., SUNY, and the Univ. of San Francisco.

Plans for construction of sediment traps were shared with:

- Ocean Sciences Centre, Newfoundland, Canada
- University of Stockholm, Sweden
- Great Lakes Engineering Company
- University of Michigan
- University of Florida
- University of North Carolina
- University of Minnesota
- Duke University

Method for culturing zebra mussel larvae were shared with

- U.S. Fish & Wildlife Service Toxicology Laboratory
- University of Guelph, Canada
- Rensselaer Polytechnic Institute, Troy, NY

Other:

- Filtration device developed at GLERL is being marketed by a small business (St. John Associates).
- Great Lakes Engineering Co. is using plans developed at GLERL to build and market a photosynthetron.

GLERL and Great Lakes Education

In keeping with NOAA's desire to better inform the public of its research activities, GLERL is involved in a number of Great Lakes community education programs. In FY 94 GLERL staff:

- made presentations concerning the Great Lakes and GLERL programs at area schools and gave several tours of our facility to interested students and teachers.

- in conjunction with the Lake Michigan Federation, the R/V *Shenehon* worked with students from Muskegon High School studying zebra mussel densities (J. Grimes, Coordinator). In addition, the *Shenehon* was used several times to provide cruises for various other student groups.
- represented GLERL at several community environmental awareness functions.
- participated as judges in Lincoln Elementary school science fair (J. Cavaletto, Coordinator).
- participated as a guest speaker in Career Day at the University of Michigan (C. Sellinger).

Partners for Excellence

This year marks our fifth year involved in a partnership with the Science Department of the Ann Arbor Public Schools' Partners for Excellence Program (T. Nalepa, GLERL Coordinator). This program seeks to enrich the schools' curriculum in the area of environmental science, particularly with respect to the Great Lakes and aquatic sciences. Designated partnership activities include:

- ◆ Providing mentors to help students with science fair projects.
- ◆ Providing practical "hands-on" experience to promising science-oriented students via participation in a Student Volunteer Program.
- ◆ Providing information on careers in environmental science and acting as consultants for the science curriculum.
- ◆ Inviting science teachers to laboratory-sponsored seminars.
- ◆ Assisted Thurston Elementary School with replacement of a weather station that was destroyed by vandals over the summer—provided engineering assistance and installed new weather instrumentation.

Great Lakes Education Kit

The Publications Unit has compiled and is continually updating a kit composed of materials for teachers who wish to integrate Great Lakes education into their curriculum. The kit is available on a loan basis. Contact the Publications Unit for more information.

Southeast Michigan Science Fair

In conjunction with the 34th Annual Southeast Michigan Regional Science Fair, GLERL sponsored awards for outstanding projects in aquatic science in each of the Science Fair divisions: Senior Projects, Junior Projects, and Junior Models and Collections. GLERL staff (T. Croley II, T. Hunter, D. Lee, D. Schwab, H. Vanderploeg, J. Saylor, and A. Beeton) acted as general science fair judges and also as judges for the GLERL award in the Southeast Michigan Science Fair.

Satellite Technology Education Program (STEP)

This is a NASA and NOAA program to introduce and use satellite images and data in the classroom (K-12). This program was coordinated and implemented by the Environmental Research Institute of Michigan (ERIM). GLERL participates by providing CoastWatch data and products.

Student Volunteer Program

GLERL and the Ann Arbor Public Schools established a Student Volunteer Program authorized by the Civil Service Reform Act of 1978 (Public Law 95-454). This program provides selected high school students with the opportunity to perform volunteer work at GLERL after school.

Bring A Girl to Work Day

GLERL's Federal Women's Program Coordinator began GLERL's participation in "Bring a Girl to Work Day." Each year, girls are invited to spend the day at GLERL observing and working with several GLERL employees. Some of their activities include collecting and testing water samples, labelling sample containers, grinding sediment samples, and digitizing zebra mussels. They are given presentations, a lab tour, a special lunch, and a certificate for their participation in the program.



Participants in "Bring a Girl to Work Day" spend time in the laboratory conducting experiments and learning the duties of a scientist.

SEMINARS

The following seminars were held at GLERL during FY 94:

Meteorological and hydrological forcing in a Great Lakes coastal wetland. D. Mille, U.S. Dept. of Agriculture, South Region Research Center. November 23, 1993.

The dynamic Lake Maracaibo. Gustavo Parra Pardi, Caracas, Venezuela. February 7, 1994.

Coastal geologic processes involving ice with examples from Alaska, Lake Michigan, and Lake Erie. P.W. Barnes, U.S. Geological Survey, Menlo Park, CA. February 14, 1994.

Lake Biwa-ko, Japan. Shuichi Endoh, Shiga University, Japan. February 22, 1994.

Age composition of an unexploited population of Humpback Lake Trout in Lake Superior. M.K. Burnham-Curtis, National Biological Survey--Great Lakes Center. March 3, 1994.

Decline and recovery of Lake Trout populations near Isle Royale. G.L. Curtis, National Biological Survey--Great Lakes Center. March 3, 1994.

Tracing pollutants down the Mississippi: Twin cities to the Gulf. B. Meade, U.S. Geological Survey, Denver, CO. March 4, 1994.

High resolution current measurement in shallow water. A. Lohrmann, SonTek, Inc. March 25, 1994.

Carbon cycling in pelagic ecosystems: Retentiveness, size structure, and the role of protozoa. H.J. Carrick, San Francisco State University. March 29, 1994.

Extending Lake Michigan historical lake-level record into geologic time: The systematic development of multiple detailed relative lake level curves. Todd Thompson, Indiana Geological Survey. April 13, 1994.

GLERL's Geographic Information System (GIS) Laboratory. D.H. Lee, GLERL. April 21, 1994.

Groundwater flux into eastern Lake Michigan. Cynthia Sellinger, GLERL. April 27, 1994.

Find the fish: Using PROC SQL to build a relational database for a mark-recapture study. S.R. Nelson, National Biological Survey--Great Lakes Science Center. May 5, 1994.

Development of *in vitro* assays for assessing the immunomodulatory effects of environmental contaminants on Great Lakes Salmon. G.E. Noguchi, National Biological Survey--Great Lakes Science Center. July 7, 1994.

STAFF

Office of the Director

Beeton, A.M. - Director
 Williams, R.S. - Secretary
 Reid, D.F. - Asst. to Director (Acting)
 Kulpanowski, K.A. - Certified Industrial Hygienist

Administrative Services

Mark, S.V. - Head
 Lashbrook, E.K.
 Mull, R.C.

Publications Unit

Darnell, C.M. - Head
 Sparks, K.J.

Computer and Information Systems Group

Spalding, G.E. - Head
 Lojewski, N.L. - Secretary
 Del Proposto, D.J.
 Fenton, J.F. Library Facility
 Herche, L.R. Carrick, B.J. - Librarian
 Lefevre, J.T. Threm, S.M.

Marine Operations and Instrumentation Laboratory

Soo, H.K. - Head
 Lojewski, N.L. - Secretary
 Bell, G.L.
 Lane, J.C. R/V *Shenehon*
 Lee, J.P. Morse, D.V. - Ship Operator
 Miller, T.C. Burns, W.R.
 Muzzi, R.W. Grimes, J.E.
 Ruberg, S.A. Wilkinson, J.A.*
 Shrum, A.F.

Biogeochemical Sciences Division

Landrum, P.F. - Head (Acting)
 Fohey, J.A. - Secretary
 Bootsma, H.^N Kane-Driscoll, S.^c
 Cavaletto, J.F. Krause, A.E.^c
 DeLaSierra, R.U.^c Lang, G.A.
 Eadie, B.J. Lansing, M.B.
 Fahnenstiel, G.L. Liebig, J.R.
 Fanslow, D.L. Lynn, J.A.
 Faust, W.R. Morehead, N.R.
 Gardner, W.S. Nalepa, T.F.
 Gluck, A.A.^c Nelson, A.S.*
 Gossiaux, D.C. Pernie, G.L.
 Gostenik, G.W.^c Quigley, M.A.
 Harkey, G.A.^c Robbins, J.A.
 Hartson, D.J.^c Rood, R.W.^c
 Hsieh, J.L.^c Vanderploeg, H.A.
 Johengen, T.H.^c VanHoof, P.A.
 Johnson, J.R.^c Wang, H.W.^c

Physical Sciences Division

Quinn, F.H. - Head
 Wrenn, B.S. - Secretary
 Assel, R.A. Leshkevich, G.A.
 Bahatia, R.* Liu, P.C.
 Bratkovich, A.W. Lofgren, B.M.^c
 Clites, A.H. McCormick, M.J.
 Cochran, S.^c Meyer, D.E.^c
 Croley, T.E., II Miller, G.S.
 Dong, D.Y.^c Muhr, G.C.
 Havens, W.^c Norton, D.C.
 Hawley, N. O'Connor, W.P.^c
 Hibner, B.A.^c Saylor, J.H.
 Hufnagel, J.A.* Schwab, D.J.
 Hunter, T.S. Sellinger, C.E.
 Jones, B.H.^N Wood, E.^c
 Lee, D.H.

* - Indicates WAE Employee
 = - Indicates Co-op Employee
^N - Indicates NRC Fellow
^c - Indicates CILER Employee

VISITING SCIENTISTS

- Dmitry Beletsky
Russian Academy of Sciences, St. Petersburg, Russia
(Soros Foundation Fellow)
- Harvey Bootsma
National Research Council
Post Doctoral Research Fellow
- Albertina Corona
Institute for the Control and Conservation
of Lake Maricaibo, Venezuela
- Dr. Virgil Frizzell
Office of Energy and Marine Geology
U.S. Geological Survey
- Burt Jones
National Research Council
Post Doctoral Research Fellow
- Susan Kane-Driscoll
National Research Council,
Post Doctoral Research Fellow
- Dr. Jussi Kukkonen
University of Joensuu, Academy of Finland.
- Peter Lavrentyev
Fulbright Scholar
Russia
- Paul Marangelo
Mystic Seaport Museum, Mystic, Connecticut
- Nerva Morales
Institute for the Control and Conservation
of Lake Maricaibo, Venezuela
- Kenton Stewart
State University of New York, Buffalo
- Dr. Janusz Tomazek
International Research and Exchanges Board, Inc.,
Rzeszo'w University of Technology, Rzeszo'w, Poland.
- Hong Wei Wang
Beijing Medical University
The People's Republic of China

FY 94 PUBLICATIONS

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*Capitalized names represent GLERL authors.

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ACRONYMS

AAPS	Ann Arbor Public Schools
ADCP	Acoustic Doppler Current Profiler
AGU	American Geophysical Union
ANS	Aquatic Nuisance Species
AOML	Atlantic Oceanographic Marine Laboratory
ARCS	Assessment and Remediation of Contaminated Sediments
ASLO	American Society for Limnology and Oceanography
ASSP	Approved Species-Specific Protocol
ASTM	American Society for Testing and Materials
AVHRR	Advanced Very High Resolution Radiometer
BaP	Benzo(a)pyrene
CCIW	Canada Centre for Inland Waters
CD-ROM	Compact Disk - Read Only Memory
CER	Coordinated Ecosystem Research
CHARM	Coupled Hydrosphere Atmosphere Research Model
CILER	Cooperative Institute for Limnology and Ecosystems Research
COP	Coastal Ocean Program
CSCS	Consolidated Scientific Computing System
CTD	Conductivity, Temperature, and Depth
CZE	Capillary Zone Electrophoresis
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
DON	Dissolved Organic Nitrogen
DYNMX	Dynamic Mixing Model
EC ₅₀	Effective concentration at which 50% of worms will leave sediment.
EEO	Equal Employment Opportunity
EMAP	EPA Mapping Program
EPA	U.S. Environmental Protection Agency
ERIM	Environmental Research Institute of Michigan
ERL	Environmental Research Laboratories
ERS	Earth Resources Satellite
ESDIM	Earth System Data and Information Management
FEDLINK	Federal Library and Information Network
FIBS	Field by Information Blending and Smoothing
FNOC	Fleet Numerical Oceanographic Center
FY	Fiscal Year
GB	Gigabyte
GC/MS	Gas Chromatography/Mass Spectrometry
GCM	General Circulation Model
GIS	Geographic Information System
GLCFS	Great Lakes Coastal Forecast System
GLERL	Great Lakes Environmental Research Laboratory
GLFS	Great Lakes Forecasting System
GLIN	Great Lakes Information Network

GOES	Geostationary Observational Environmental Satellite
GPS	Global Positioning System
HCBP	Hexachlorobiphenyl
HOC	Hydrophobic Organic Compound
HPLC	High Performance Liquid Chromatography
IAGLR	International Association for Great Lakes Research
IDIDAS	Interactive Digital Image Display and Analysis System
IJC	International Joint Commission
IMSL	International Mathematics and Statistical Library
LAN	Local Area Network
LATEX	(Gulf Marine Minerals Management) Louisiana Texas Experiment
LAVc	Local Area VAXcluster
LC50	Lethal concentration in environment resulting in 50% mortality.
LD50	Lethal dose which results in 50% mortality of population.
LORAN-C	Location Radio Navigation-Coordinates
MAR	Mississippi Atchafalaya River
MARC	Machine-Readable Cataloging
MCC	Midwest Climate Center
MCSST	Multi-Channel Sea Surface Temperature
MICIS	Midwestern Climate Information System
MIL	Marine Instrumentation Laboratory
MLC	Michigan Library Consortium
MOIL	Marine Operations and Instrumentation Laboratory
MRP	Mississippi River Plume
MRP/GS	Mississippi River Plume/Gulf Shelf
MRP/IGS	Mississippi River Plume/Inner Gulf Shelf
NBS	National Bureau of Standards
NDBC	National Data Buoy Center
NECOP	Nutrient Enhanced Coastal Ocean Productivity
NESDIS	National Environmental Satellite, Data, and Information Service
NIST	National Institute of Standards and Technology
NLIN	NOAA Library and Information Network
NLSST	Non-Linear Sea Surface Temperature
NMC	National Marine Center
NOAA	National Oceanic and Atmospheric Administration
NOCN	National Ocean Communication Network
NOS	National Ocean Service
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSIPS	NRL Satellite Image Processing Systems
NURP	National Undersea Research Program
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OCLC	Online Computer Library Center
OCNMAP	Ocean Map
OSU	The Ohio State University
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PDMS	Polydimethylsiloxane
PI	Principal Investigator
PMEL	Pacific Marine Environmental Laboratory

PMF	Probable Maximum Flood
POC	Particulate Organic Carbon
POM	Particulate Organic Matter
RAMS	Regional Atmospheric Modeling System
RNN	Regional Network Node
ROV	Remote Operated Vehicle
SABRE	South Atlantic Bight Recruitment Experiment
SAR	Synthetic Aperture Radar
SEAS	Shipboard Environmental Acquisition System
SIMS	Stable Isotope Mass Spectrometer
SPM	Suspended Particulate Material
SST	Sea Surface Temperature
SUNY	State University of New York
TM	Thematic Mapper
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VACM	Vector Averaging Current Meter
WARFS	Water Resources Forecasting System
WLLN	Washtenaw-Livingston Library Network
WRIPS	Wave Rider Information Processing System
XBT	Expendable Bathythermograph